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TECHNOLOGY IMPLEMENTATION

High Speed Manufacturability Polymeric Tray

Final Technical Report STP 1022

Results and Accomplishments (May 2000 - October 2001)

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Moisture entrapment in the seal area is the primary cause for seal defects. Lower line speeds and/or lower fill temperatures were identified as solutions to reduce these type defects. To a much lesser degree did vacuum create seal defects and was a function of the type product that was being filled. Higher fill weights in combination with lower vacuum were identified to as solutions to reduce this type defect.

The flange thickness variation of the tray had a significant impact on the required seal conditions. An increased variation in the flange thickness requires longer seal times, but reduces the maximum throughput rate of the sealer. Improving the flange thickness variation needs to be considered to increase the line capacity to the target rate to 20 trays/min.

The thermal process is the most likely bottle neck of the manufactures process. Retort studies demonstrated significant reductions in process times by utilizing rotational retort processes. The cook time for Pork Sausage Links in Brine was reduced by 24% and for Creamed Ground Beef by 58%.

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1. Results and Accomplishments

1.1. *Introduction and Background*

Earlier Manufacturability Studies examined Polymeric Tray Pack production at fixed production rates which were either based on semi-commercial rates (Star Foods: 2 – 4 trays/min) or conservative non-optimized rates (Rutgers FMTF: 9 – 10 trays/min). However, the commercial-scale Heat Sealer at Rutgers routinely processes non-military polymeric trays at 15/minute and the heat sealer-only portion of the production line is rated at 30 trays/minute. Actual commercial operating rates would be expected to have significant impacts on production economics and the impact sustained by any limiting specification levels.

Since the inception of the Tray Pack Ration, the product has been processed and packaged in a heavy metal tray shaped can with a double seamed metal lid. As a result of the Process Action Team at DSCP, The Polymeric TrayPack Program at NATICK and CRAMTD Short Term Project STP #10 at the Rutgers University CAFT, an alternative package was developed utilizing a polymeric tray body and a laminated foil and polymer lidstock. This alternative package was necessary due to a declining supplier base for the metal tray can and lid (one supplier) and various problems with the interior coating of the cans. The square metal can was also difficult to open and presented a safety hazard from the sharp edges on the lid after opening. Manufacturability studies performed both Star Food and the CAFT FMT Facility plus two production tests (one at Wornick and one at Stegner Foods) revealed product-compatibility issues with the specifications as adapted from the metal can for the polymeric tray.

The polymeric tray has been field tested by both the Army and the Marine Corps and has been found to be acceptable. Shelf life testing by SBCCOM has determined that the polymeric tray will provide similar quality to the metal tray over a 36 month period. DSCP has outlined its plans to phase in the polymeric tray during the next procurement cycle. In order for that phase-in to work smoothly and successfully, each of the specifications must be reviewed and tested for revision to the polymeric tray. The maximum processing parameters for the polymeric tray have never been established, nor has alternate processing techniques such as rotation during retorting been reviewed. The polymeric tray replacement for the metal tray-can is an urgent program of great importance to the Military Services, especially since past metal cans are showing evidence of premature deterioration.

1.2. *Objectives*

This proposal is to perform a Short Term Project (STP) under the CORANET Contract, SP0103-96-D-0016. The objective of which is to verify and test the specification requirements for production of thermostabilized items in polymeric trays. The specification requirements will be tested to determine the attainable limits imposed by process capability in order to maximize production while maintaining the current quality of the product for a period of 36 months and the performance of the package at the level to which the services are now accustomed.

1.3. *Results and Conclusions*

This project focussed on the interactions that selected product, process and packaging variables have on packaging and retort efficiencies. The project used Pork Sausage Links in Brine and Creamed Ground Beef as the two test products.
It was concluded that moisture entrapment in the seal area is the primary cause for seal defects. This moisture entrapment was either caused by splashing during filling (low viscosity products) or by condensation of headspace moisture in the seal area (hot fill products). Lower line speeds and lower fill temperatures were identified as solutions to reduce these type defects. To a much lesser degree did vacuum

create seal defects and could be correlated to the type product that was being filled. Higher fill weights in combination with lower vacuum were identified as solutions to reduce this type defect.
It was also concluded that the flange thickness variation had a significant impact on the sealing conditions that needed to be used. Larger variations in the flange thickness required longer seal time in order to assure that the seal width exceeded the minimum specification requirements. Seal times of 3.5 seconds were found to be adequate to produce a consistent wide seal. Longer seal times however reduced the maximum throughput rate of the sealer to 15 trays/min. Further investment in reducing the flange thickness variation should be considered to increase the line capacity once the packaging line speed becomes the bottle neck of the process.
In the economic analysis, it was determined that the thermal process was currently the most likely bottle neck in a manufactures process. Retort studies clearly demonstrated the very significant reductions in process times that can be obtained by utilizing rotational retort processes. The cook time for Pork Sausage Links in Brine was reduced by 24% and for Creamed Ground Beef by 58%. The racking system that was developed for this tray was able to support the tray during these rotating retort processes without creating abrasion type defect in the seal area.

1.4. Recommendations

- Evaluate the impact of anomaly type defects in the seal area caused by moisture on the seal strength. Relaxation of the specification requirements in this area will have significant impact on the manufacturability of these type products
- Evaluate the impact of Residual Gas on the shelf life and package integrity. Relaxation in this area will have a significant impact on the manufacturability of these type products.
- Asses with producer of tray the reasons for flange thickness variation and possible solutions to reduce the variation which can lead to decreased seal time and increase throughput rates
- Evaluate different nozzles designs that prevent moisture contamination of the seal area
- Evaluate systems that would accommodate hot fill products without condensation of headspace moisture in seal area. Hot fill products will reduce process times and increase line capacity.
- Evaluate additional products to identify additional filling, sealing and retort issues and develop guidelines for resolution.

2. Program Management

The project was awarded on May 24, 2000 under contract SP0103-96-D-0016, Delivery Order 0017 with a total obligation of $240,050. Performance period for this delivery order was set for 11 month (April 24, 2001).

The following modifications were issued:

April 18, 2001	0017/01	performance period is extended from 4/24/01 to 5/24/01 at no additional cost
May 7, 2001	0017/02	performance period is extended from 5/24/01 to 9/30/01 at no additional cost, and reallocation of budget as outlined in letter from Rutgers, dated April 19, 2001
Sept 30, 2001	0017/03	performance period is extended from 9/30/01 to 10/31/01 at no additional cost.

Reason for the first two modifications was due to the excessive variability in flange thickness of the tray produced by Rexam, requiring new trays to be produced. Production of these trays was however delayed due to delays in production contract awards. The third extension was awarded to complete the final report

3. Short Term Project Activities

3.1. Production System Analysis

The objective of this task was to perform a production systems-analysis including subsystems for filling, sealing and retorting of product in polymeric trays and determine the impact of production rates and investments on cost per unit.

The analysis was performed by building a production model within an Excel Spreadsheet of a typical Polymer Tray Pack Production System including filling, sealing, and retorting and use data available from the manufacturability studies performed earlier at Rutgers. The model calculated the cost per unit for production of polymeric trays based capital investment, production rates, production yields, production efficiencies and resource requirements. Case studies, using various assumptions, were used to determine the impact of these assumptions on the unit cost.

The economic model and analysis clearly demonstrated that the retort operation is the most capital intensive part of the process. More than likely the available retort capacity in a plant will dictate the packaging line speed. Therefore, the emphasis of this project needed to focus primarily on increasing the capacity retort process. As a secondary objective, the project needed to focused on the packaging line speed, to determine if 20 trays per minute could be achieved and how process yield would be affected as function of selected product, process and packaging parameters.

An Interim Program Review was held on August 11, 2000, with the CORANET Program Manager, members of the Joint Steering Group and Industry representatives. Based on these case studies recommendations were made regarding a detailed experimental study for the retort and the packaging processes. The recommended variables for retorting studies were rotation versus static cooking, headspace, and retort rack configurations. The recommended variables for filling/sealing experiments were fill temperature, viscosity, fill weight, vacuum, seal time and line speed.

Details of the economic model and analysis, including the various case studies are documented in Technical Working Paper #215.

3.2. Process and Product Development

As a first step, a complete process and product development activity was executes to determine formulations and procedures that would yield acceptable product. Samples of product were submitted to Natick to confirm acceptability.

The Creamed Ground Beef required significant product development activities to ensure that the product was stable in a rotating retort. Initial samples tended demonstrate fat separation during the retort process. Careful selection of ingredients in combination with lean ground beef resulted in product that was found to be acceptable.

Once the product formulation and process descriptions were identified, various packaging and food ingredients were acquired to support the experimental and production phases of this project. Each of the technical working papers (TWP 213, 214, 216, 217 & 218) document the suppliers of the main ingredients and packaging materials.

3.3. Retort Variable Study

The objective of this variable study was to determine the effect of residual gas, product viscosity, rack configuration and rotational speed on retort cycle times. Two products: Pork Sausage in Brine and Creamed Ground Beef were used for this study. It was concluded that a rotational process significantly

decreased the average required cook time of Pork Sausage in Brine by 24% and of Creamed Ground Beef by 59%.

Rotational retort process can enhance both the external heat transfer as well as the internal heat transfer of the tray. The external heat transfer is enhanced by increased water flow around the container. The internal heat transfer can be increased if the headspace gas can be forced to move through the liquid phase of the product and thus inducing a "forced convective flow". Increased headspace, up to a certain limit, will increase the effectiveness of this forced convection. The movement of the headspace through the liquid phase and its ability to induce forced convective flows is however impacted by the viscosity of the liquid phase and the rotational speed of the retort. Very viscous products, such as pumpkin pie, are too viscous and rotation can not force the headspace gas through the product.

Rotation retort speed needs to be optimized to obtain maximum efficiency of the forced convective flows. Maximum efficiency is obtained when the air bubble cuts through the liquid phase and not along the perimeters of the tray (=speed too low) or not move at all (=speed too fast).

Detailed results of the retort studies are documented in three technical working papers (TWP-213, 214 & 216). A summary of these studies is given in the sections below.

3.3.1. Pork Sausage Links in Brine

Pork Sausage Links in Brine has a low viscous liquid. The rotational speed (5 & 15 rpm) seemed to be less effective than seen in the other product. In matter of fact, higher residual gas resulted in slower heat transfer rates in the rotational process. This seems to indicate that the air bubble was not able to cut through the liquid phase, but instead traveled along the perimeter of the tray. In these cases, residual gas can act as an insulator rather than an agitator. Natural convective flows of the brine seem to be sufficient in transferring the heat to the sausage links and the heat transfer seemed to be limited by the external heat transfer which improved when the flow of the heat transfer media was increased by using retort rotation. To obtain maximum performance, this product should be packed off with a relative low residual gas level and be processed with maximum water flow in between the container.

Program	Res Gas	Cook Time	% Change
Static	150	31.2	0%
Static	350	33.9	+6%
Rotation	150	23.8	-24%
Rotation	350	26.0	-17%

Table #1: Average Cook Time and Cook Time Reduction for Pork Sausage Links in Brine

3.3.2. Creamed Ground Beef

Creamed Ground Beef was made with two different sauces: one low to medium viscous sauce (T-T) and one medium to high viscous sauce (P-W). Rotation speed with high residual gas was quite effective in increasing the heat transfer rate, indicating that the air bubble cut through the sauce.

The low to medium sauce (T-T) was made with a special starch, THERMTEX® starch from National Starch, that was developed specifically for retort applications. This starch does not develop its full viscosity at batch preparation temperatures (180 F), but requires retort temperatures (240-250F) to fully

develop its viscosity. This increases the heat transfer rates in rotational retort processes, as the headspace gases are more effective to induce the forced convective flows in the sauce.

Use of the , THERMTEX® starch, in combination with rotational retort processing and higher residual gas, resulted in very significant reduction in average required Cook Time (59%).

Program	Res Gas [cc]	Starch [-]	Cook Time [min]	% Change [-]
Static	150	P-W	75.8	0%
Static	150	T-T	78.4	3%
Static	350	P-W	87	15%
Static	350	T-T	92.3	22%
Rotation	150	P-W	53.3	-30%
Rotation	150	T-T	39.4	-48%
Rotation	350	P-W	44.1	-42%
Rotation	350	T-T	30.9	-59%

Table #2: Average Cook Time and Cook Time Reduction for Creamed Ground Beef

It should be noted that, while the heat transfer rate of products with medium viscosity sauces and gravies can be improved in rotational retort process by increasing the residual gas, static retort processes should be produced with a low residual gas level for optimal performance.

3.4. Packaging Variable Study

The objective in this task was to determine the interactions between variables such as line speed, product fill temperature, product viscosity, fill volume, vacuum, seal time, residual gas and seal defects.

At the start of the study, it was discovered and documented that the quality of the flange thickness had an over riding effect on the quality of the seal. Increased variability of the tray flange thickness led to increased variation in the seal width and localized narrow and unacceptable seals. To overcome this defect, seal times needed to be increased, in order to melt away the thick parts of the flange in order to seal also the thinner parts of the flange. Increased seal time, however, had a direct effect on the maximum through put rate of the packaging line. Table #3 displays the required seal time parameter as function of the tray flange quality. Table #4 displays the effect of seal time on the maximum throughput that can be achieved on the Raque Heat Sealer as function of the seal time and vacuum time

Tray ID	Tray Weight (gram)	Flange Thickness (mil)	Range (mil)	Seal Time (sec)
7991 (6/20/00 3A)	155.5/5.6	68.1/4.1	14	2.5
7991 (6/16/00 4X)	156.7/0.3	69.3/6.8	20	4.5
7991 (6/15/00 4A)	155.4/0.7	66.0/8.1	25	6.5
8950 (Jan 01 #456)	155.9/0.4	72.1/6.8	20	3.5-4.5
9743 (5/25/01 B)	156.2/0.2	67.1/6.0	18	2.5-3.5
9743 (5/26/01 A)	155.6/0.3	67.0/5.8	17	2.5-3.5

Table #3: Required Seal Times as function of Flange Thickness Variation

Vacuum Time Seal Time	0.2 sec	1.0 sec	1.5 sec
2.5 sec	24	19	17
3.0 sec	21	17	15
3.5 sec	18	15	13
4.0 sec	16	13	12
4.5 sec	14	12	11

Table #4: Maximum Capacity Raque Heat Sealer [trays/min] as function of Seal Time and Vacuum Time

Because of the significant effect of flange uniformity on the seal quality, experiments were postponed till a large production run was made at Rexam that would yield a uniform population of trays from which the experiments could draw upon. This large production run was delayed due to a delay in the release of production contracts, leading to a delay in the experiments and completion of this short term project. Trays were finally produced by the end of May.

All experiments were produced with Tray Lot ID 9743 which were produced over a two day period at Rexam Containers. A total of 384 trays with Pork Sausages Links and 778 trays with Creamed ground Beef were packed off and analyzed for seal defects as function of product, process, and package variables. Detailed results of the packaging studies are documented in technical working paper (TWP-217 & 218). The sections below are a summary of these studies.

3.4.1. Pork Sausage Links in Brine

Pork Sausage Links in Brine required placement of 72 sausage links inside the tray. This was a manual and labor intensive operation. Once the tray was filled with sausage, the tray was placed in the carrier of the sealer and filled with a brine solution. The consistency of brine is that of water and the liquid filling process tended to "wet" the seal area as it splashed. Therefore, the seals needed to be dried before sealing, in order to prevent anomalies in the seal area. The study determined that, under the current specifications, the packaging of this product did not lend itself to high production speeds as the seal drying became less effective and resulted into increased anomalies in the seal area. While this type of defect is classified as "minor", it has the potential to cause lot rejection. This forces the producer to remove these tray from the line and recycle the product if possible.

Product Temperature was an important factor in controlling seal defects. Trials were made that used refrigerated sausages and a hot brine fill. The resulting product had an average product temperature of about 120 F while it entered the sealing chamber. This led to moisture condensation in the seal area and consequently large number of anomalies in the seal, even though the seals were carefully dried before entering the seal chamber.

It was determined that longer seal times can reduce the effect of a moist seal area by melting away the top layer of the flange and pushing the molten polypropylene with the moisture to the edge of the seal. The anomaly appeared in that case in the edge of the seal. It was however difficult to determine if the anomaly is inside the first 1/16" of the seal (scorable) or if the seal started right after the anomaly (not scorable).

The US Army Natick Soldier Center has evaluated the minor anomaly and suggested that the minor anomaly, caused by moisture, should not be scored as a defect, as long as there is at least 1/8" wide seal. A

revised specification is under development. This revised specification would allow for higher line speeds and higher fill temperatures while not sacrificing packaging yield.

It was determined that vacuum and fill weight had no significant effect on the seal quality and thus the specification limit for residual gas was not causing incremental seal defects. We should however note that the sausages were completely submerged in the brine at either fill weight, an important aspects as we will discuss later. It should also be noted that higher fill weights, require less vacuum to be applied in order to meet the finished product residual gas specification. This will have a positive effect on the sealer capacity. It should also be noted that higher fill weights, while not causing additional defect on the continuous motion sealer, it might cause additional defects in an indexing heat sealer.

While the residual gas did not directly effect the packaging yield, it is still suggested that the maximum residual gas level is relaxed as will be explained later.

3.4.2. Creamed Ground Beef

Creamed Ground Beef was filled in a single stage filling operation, using a single Raque piston filler. Two sauce consistencies were tried and neither one led to seal contamination, nor did the line speed or product temperature have a significant effect on seal contamination at the filling station.

The most important factor that effected the seal quality was the product temperature. Even though the seals were clean and dry entering the sealing station, condensation from the hot product caused a significant number of seal defects (anomalies). This observation was consistent with the observation noted in the Pork Sausage in Brine product.

While the type of defect that it created was classified as "minor", it's potential to cause lot rejection, forces the producer to remove these tray from the line and recycle the product if possible.

As was the case in Pork Sausage Links with Brine, longer seal times reduced the effect of moisture in the seal area by melting away the top layer of the flange and pushing the molten polypropylene with the moisture to the edge of the seal. The anomaly appeared in that case in the edge of the seal. It was, however, difficult to determine if the anomaly is inside the first 1/16" of the seal (scorable) or if the seal started right after the anomaly (not scorable).

Contrary to the Pork Sausage product, it was determined that fill weight had a significant effect on the seal quality. Specification fill weight created more defects than trays filled to 100 oz. Vacuum was an order of magnitude less significant than fill weight. Strong vacuum could be pulled without causing defects in the seal area, as long as the tray was filled significantly above the specification limit. A more detailed explanation for the cause and the interaction with product characteristics will be given in section 3.6.1.3

The US Army Natick Soldier Center has evaluated higher residual gas levels and made recommendations to increase the maximum allowable level. This relaxation in specification limit will have a significant effect on the vacuum that needs to be pulled, resulting in an increase of maximum throughput rate and reduction in seal defects caused by vacuum wrinkles.

3.5. Sample Production for Natick

Product Samples of both Pork Sausage Links in Brine and Creamed Ground Beef were produced in August 2001 for the benefit of the US Army Natick Soldier Center for package integrity and organoloptic analysis. Product was packed off at three different vacuum levels (10", 14" & 21" Hg), resulting in approximately

150, 250 and 350 cc residual gas. Product was sterilized in either a static retort or a rotational retort process, resulting in a total of 12 different lots. The production data is summarized in appendix 4.7.

3.6. Review Current Specifications

Final-performance specifications and the relationships between specification levels and production rates and yields will be reviewed in the following section. The two products that were studied under this Short Term Project will be reviewed first. In the third section, specification limits associated with the package will be reviewed

3.6.1. Polymeric Tray Product Items

Table #5 lists all products that are packed off in Polymeric Half Steam Table Trays. The products can be grouped in to categories based on expected behavior during the filling and sealing process. Table #6 explains the various category descriptions. It is expected that packaging issues are somewhat category specific. However, a finer granulation of categories might be in place as the knowledge base is built.

Product Name	**NSN**	**Catagory**
Ham Slices in Brine	8905-01-446-0215	1
Pork Sausage Links in Brine	8905-01-455-3547	1
Beef Patties in Broth	8940-01-455-1884	1
Chicken Breast in Gravy	8940-01-445-5737	2
Meatballs in Brown Gravy	8940-01-455-1873	2
Pork Ribs, Boneless	8940-01-455-1882	2
Ham Slices in Spice Sauce	8940-01-455-1883	2
Turkey Slices with Gravy	8940-01-455-4611	2
Potatoes, Diced, in Sauce	8940-01-455-1877	2
Spaghetti with Meatballs in Sauce	8940-01-455-1880	2
Sweet Potatoes, Glazed	8940-01-455-1878	2
Mashed Potatoes with Gravy	8940-01-470-9838	2
Omelet w Smoked Sausage and Potatoes	8940-01-472-3788	2
Pork Sausage in Cream Sauce	8940-01-470-3204	4
Potatoes with Bacon Pieces in Sauce	8940-01-455-1871	4
Chicken Chow Mein	8940-01-446-0214	4
Beef Stew	8940-01-455-1875	4
Pork and Beans	8940-01-455-1879	4
Beef Strips with Green Peppers and Gravy	8940-01-455-3539	4
Corn Beef Hash	8940-01-455-3548	4
Beef, Ground, Creamed	8940-01-455-4609	4
Chicken w Vegetables in Teriyaki Sauce	8940-01-470-3181	4
Chili with Beans	8940-01-470-3190	4
Stuffing	8940-01-470-9838	4
Scrambled Eggs	8940-01-470-3097	4
Scrambled Eggs with Cheese, Western Style	8940-01-470-3138	4
Omelet with Bacon and Cheese	8940-01-470-3145	4
Beans with Rice and Bacon	8940-01-455-1885	6
White Rice	8940-01-445-5736	6
Rice Oriental Style	8940-01-455-1874	6

Lasagna with Meat Sauce	8940-01-455-3542	9
Beef Chunks with Noodles in Sauce	8940-01-470-3154	9
Cherry Dessert	8940-01-455-1870	10
Blueberry Dessert	8940-01-455-1872	10
Apple Dessert	8940-01-455-1876	10
Chocolate Pudding	8940-01-470-1881	10

Table #5: Polymeric Tray Product List

1= Cold placeble with pumpable low viscosity liquid (brine)
2= Cold placeble with pumpable light to medium viscosity liquid
3= Hot placeble with pumpable medium viscosity liquid
4= Cold pumpable type product
5= Hot pumpable product
6= Cold viscous material, requiring manual filling
7= Hot viscous material, requiring manual filling
8=
9= Complex material
10= Dessert

Table #6: Category Descriptions

3.6.1.1. Pork Sausage Links in Brine

3.6.1.1.1. Net Weight

Specification: *"The average net weight shall be not less than 90 ounces. No individual polymeric tray shall have a net weight of less than 88 ounces".*

Net weights are determined by the weight of the sausages combined with the weight of the brine. The weight of 72 sausages was extremely repeatable, as was the accuracy of the brine fill. Besides the specification limit, it is also important to note that the net weight needs match the volume of the container. An under filled container can lead to seal wrinkles and failure to meet residual gas level. An over filled container might lead to product spillage into the seal area. Trials did determine no significant impact of fill weights between 90 and 98 oz on seal defects. Therefore no problems should be encountered meeting this specification and one might consider a higher brine fill weight to reduce the vacuum level required to maintain residual gas levels below 175 cc.

3.6.1.1.2. Drain Weight

Specification: *"The average drained weight shall be not less than 45.0 ounces. The drained weight of 72 intact sausage links in an individual polymeric tray shall be not less than 43.0 ounces".*

The drain weight was consistently measured at 50 oz or larger.. The burden of meeting this specification is put onto the supplier of the sausages. The vendor used for this sausage, produces that same sausage for metal tray. This producer had no problems meeting the specification limits.

It should however be noted that the sausages are not a "commercial off the shelf" (COTS) item and that we did not identify a second producer for this product. A single source supplier can create problems in unforeseen circumstances.

3.6.1.1.3. Number of Sausages

The specification requires: *"a minimum of 72 links in each tray".*

Because the weight of the sausages was consistent, the trays were filled based on a in-house fill weight specification rather than a count requirement. This increases the efficiency and accuracy of the filling process. This procedure maintained the count at either 72 or 73 links per tray. The burden on maintaining accurate control of sausage link weight is, again, put onto the shoulders of the supplier of the sausages. The producer had no problems maintaining accurate weight.

Filling sausages in the tray is a time consuming operation, requiring manual labor. This filling step appears to be the rate limiting step of the operations. Achieving higher fill rates might require automation, but might only be financial attractive at high volumes.

3.6.1.1.4. Fat Content

The specification requires that: *"The average fat content of the finished product shall not be greater than 33.0 % and no individual polymeric tray shall have a fat content greater than 35.0%".*

The fat content of the pork sausage in brine was measured at about 17%, well below the specification limits. The burden of this specification limit is put onto the supplier of the sausages. The producer had no problems maintaining the specification limits.

3.6.1.1.5. Salt Content

The specification requires that: *"The salt content of any individual polymeric trays shall be not less than 1.5% nor greater than 2.5%".*

The salt content is determined by the salt content in the sausage and in the brine. As a producer/packer the salt content in the final product is controlled by adjusting salt in the brine. No problems were encountered or are expected to maintain the salt content of the product between these two limits.

3.6.1.2. Creamed Ground Beef

3.6.1.2.1. Net Weight

Specification reads: *" The average net weight shall be not less than 92 ounces. No individual polymeric tray shall contain less than 90 ounces."*

This is a single stage filling process. Net weights are determined by the accuracy of the filling system and the density of the product. Besides the net weight specification, it is also important to note that the fill weight should match the volume of the container. An under filled container can lead to seal wrinkles and failure to meet residual gas level. An over filled container might lead to product spillage into the seal area. Trials did determine that higher fill weights (100 oz) were feasible with actual less seal defects. Therefore, no problems are expected to meet this specification and one might consider higher fill weight. Higher fill weights would reduce the vacuum level required to maintain residual gas levels and also increase the packaging yield by generating less seal defects that are caused by the vacuum release.

3.6.1.2.2. Drain Weight

The original drain weight specification (CTR January 11, 2000) required: *"an average minimum drain weight of 32.0 oz, and an individual drain weight of not less than 30 oz after retorting"*. This specification was changed in PCR-C-040, dated June 20, 2000 and reads now: *"The average drained weight shall be not less than 28.0 ounces. The drained weight of ground beef in an individual polymeric tray shall be not less than 26.0 ounces."*

In general, the drain weight is the most difficult specification to maintain and difficult to verify during the process. There are several factors that influence the drain weight. First, the precook yield and the fat content of the ground beef will have large effects on the finished product drain weight. Second, because this product is filled in a one stage filling process, the uniformity of the product blend and the segregation in the filling system can cause variation from fill to fill. Third, the drain weight test is done by using a US Standards No 8 Sieve. The size of the ground beef, the duration of the cook cycle, the quality of the beef, etc can effect the quantity of "beef fines" that go through this screen. This will affect the outcome of the drain weight test even though the right quantity of beef was added to the tray and the protein level is up to par.

Production for commercial sales, typically does not require drain weight testing, but relies on raw material and formulation verification to ensure that label declarations are valid. Not only are drain-weight tests time consuming, they are destructive, costly and after the fact.

3.6.1.2.3. Fat Content

The original fat content specification (CTR January 11, 2000) required: *"The average fat content of the finished product shall not be greater than 10.0 % and no individual polymeric tray shall have a fat content greater than 12.0%"*. . This specification was changed in PCR-C-040, dated June 20, 2000 and reads now: *" The fat content shall be not greater than 12.0 percent "*.

Fat is coming from two sources: sauce and beef, and is affected by the ratio of these two components in the final formula. The fat content in the sauce is accurately controlled (~3.7%) via the formulation. The fat of the beef can vary based on the type beef obtained and the degree of pre-cooking performed. By using "lean" beef for this product, which has a fat content of <10% before precooking, no problems should be encountered in meeting this specification.

If regular beef is used, which can be up to 20% fat, problems might occur, not only in meeting the specification limit on fat content, but also in fat separation during the retort process. Extensive precooking of this beef might be required.

3.6.1.2.4. Salt Content

The current specification reads: *"The salt content shall be not less than 0.5 percent and not greater than 1.5 percent"*.

The salt content is controlled via the sauce. No problems were encountered nor expected to maintain the salt content of the product between these limits..

3.6.1.2.5. Viscosity

The current specification reads: *"The viscosity of the gravy shall be not less than 3.5 cm per ten seconds or not greater than 8.0 cm per ten seconds"*.

The sauce viscosity of the finished product is primarily determined by the sauce viscosity before retorting, the starch used, the cook out losses from the beef during the process and the break down of starch during the retort process. Together with the drain weight, these two specifications are the most difficult factors to control. In general we were able to maintain the viscosity between 5 and 8 cm/10 seconds, but on occasion a slightly less viscous product was produced.

Failure to meet specification indicates, either inadequate control over the process or an unnecessary tight specification range. It is suggested that a relaxation of this viscosity specification is considered in order to make the product more manufacturable.

3.6.1.3. Packaging

3.6.1.3.1. Residual Gas

The current specification reads: *Residual gas volume in the filled, sealed and processed tray shall not exceed 175 cc.*

To stay below this maximum limit, one needs to understand and analyze its production system and the variability that could be encountered in variables that have a direct effect on residual gas. The primary variables that effect residual gas are: vacuum applied, product fill-weight, product temperature and container volume. An increased variation in any of these variables will result in an increased variability in residual gas and therefore a lower target average value for residual gas will be required to meet the specification. This last statement is explained in the example below

For example:

- assume a normal distribution in the residual gas data
- assume less than 1% of the samples can have a residual gas level that exceeds 175 cc,
- assume a standard deviation in residual gas of 20 cc,
- hence, the target average value for residual gas should less than 128 cc.

Similar production target values for different standard deviations in residual gas can be calculated for other assumptions and some are listed in the table #7. As can be seen, the larger the variation in residual gas, or a higher degree of compliance, the lower the target value has to be set for the average residual gas level.

Std Dev Res Gas [cc]	99% R.G <175 cc	99.9% R.G <175 cc	99% R.G. <250 cc	99.9% R.G. <250 cc
10	151	145	226	220
15	139	130	214	205
20	128	115	203	190
25	116	100	191	175
30	104	85	179	160

Table #7: Production target values for residual gas for 99% and 99.9% confidence interval

The primary control variable that is used to control the residual gas is the vacuum that is pulled on the container at time of sealing. A model was built that predicts the residual gas as function of vacuum, product temperature and head space volume. Table #8 and Figure #1 display the calculated residual gas levels, assuming a headspace volume of 550 cc.

Product Temp Vacuum	70 F	120 F	170 F
0" Hg	537 cc	446 cc	275 cc
5" Hg	445 cc	362 cc	197 cc
10" Hg	353 cc	278 cc	120 cc
15" Hg	262 cc	194 cc	43 cc
20" Hg	170 cc	111 cc	Flashing
25" Hg	78 cc	27 cc	Flashing

Table #8: Calculated Residual Gas (headspace volume 550 cc)

As can be seen, higher product temperature reduces the vacuum requirements in order to meet the residual gas requirements. However, care needs to be taken with high product temperatures as product flashing can happen, which means that the products start boiling. Product flashing will result in contaminated seals.

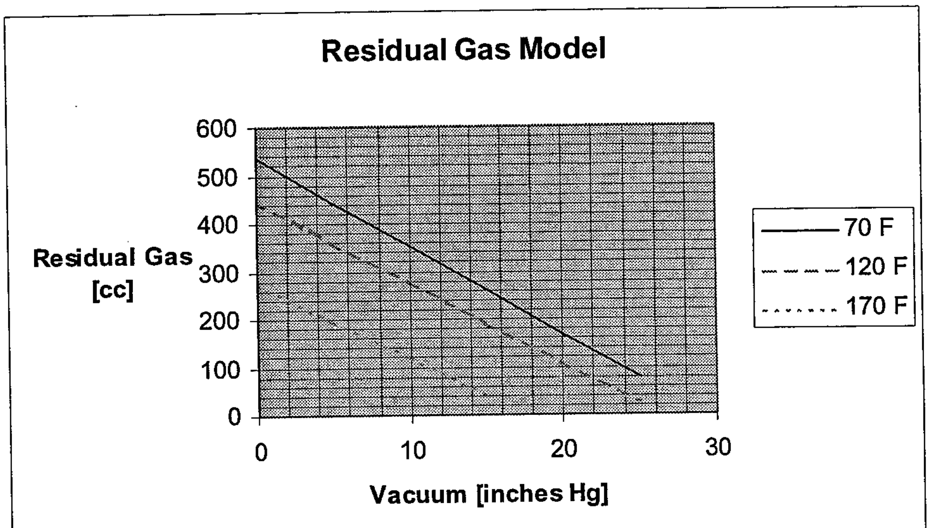

Figure #1: Predicted Residual Gas as function of Product Temperature and Vacuum

Meeting the residual gas level is achievable. However, one needs to realize that as significant high vacuum is required to achieve the target value for production in order to guarantee that 99.9% of the product meets the specification limit. Increasing the specification limit to 250 cc, would increase the target value for residual gas from 100 cc to 175 cc (std=25 cc) or a vacuum level decrease from 24" to 20" Hg. Even lower vacuums can be considered but would require higher fill weights to reduce the headspace volume or higher product fill temperature.

3.6.1.3.2. Closure Seal

The specification for closure seal reads:

The closure seal, defined as the width of fusion bonded seal at any point perpendicular to the tray flange along the tray perimeter, shall be not less than 1/8 inch wide. The first 1/16 inch of the seal at the food product edge shall be free of defects or anomalies, such as, but not limited to entrapped matter, moisture or grease. The closure seal shall be continuous along the tray flange

surface. The closure seal shall be free of impression or design on the seal surface and free of wrinkles.

Most defects that occurred in the manufacturability studies under this project were anomalies created by moisture and wrinkles caused by the vacuum. Sometimes, a contaminate on the seal plate caused an impression in the seal. Flanges contaminated with pork grease yielded acceptable strength seals with no visual defects. Inadequate seal width defects were resolved by increasing the seal time, but it should be noted that this affects the maximum throughput rate.

Moisture entrapment in the seal was the primary cause for seal defects. The moisture can either be caused by seal contamination before sealing, as was seen in the Pork Sausage in Brine product, or occur by condensation of the headspace gas into the seal as was observed in the hot fill Creamed Ground Beef production run. When moisture is present in the seal, it is incorporated in the molten polypropylene. When the seal pressure is released this incorporated moisture turns to steam and forms tiny bubbles. After the seal cools, the steam condenses and small concave anomalies remain. When the seal time is increased, the molten propylene was moved to the edges of the seal, including the entrapped moisture. The anomalies are still visible along the seal edge, but the remaining seal is free of defects. Stress tests on seals with small anomalies caused by the moisture did not indicate a weakening of the seal. **The US Army Natick Soldier Center has evaluated this anomaly and suggested that the anomaly, caused by moisture, should not be scored as a defect, as long as there is at least 1/8" wide seal. A revised specification is under development. This revised specification would allow for higher line speeds and higher fill temperatures while not sacrificing packaging yield.**

Most seal wrinkles were caused by the vacuum that pulled on the lid material while the seal is still in a semi molten phase. This resulted in movement of the lid and subsequently slight wrinkles in the seal area, primarily in the corners. There are several factors that can either help or aggravate this type wrinkle. To obtain a certain residual gas inside the tray, air needs to be removed from the tray by pulling a vacuum prior to sealing. The amount of vacuum required is determined by the head space volume and the product temperature as was demonstrated in the previous section. Once the vacuum is pulled the lid material is sealed to the tray. When the vacuum is released, the external and internal pressures of the container are equilibrated by reducing the volume of the tray. This happens mainly by drawing the top film into the container. The draw on the film can happen in several ways and depends on the product inside the container. Ideally, the film is gradually drawn into the container with the deepest draw in the center of the container. In this ideal case, the product from the center is moved to the flange area to fill the void. The consistency of the product can however prevent the movement of material. In these cases, the lid material is pulled sharply around the flange into the container, causing wrinkles in primarily the corners.

In case of the Pork Sausage in Brine, the sausages were completely submerged in the brine and the lid material had no problem moving the brine towards the flange to equilibrate the forces. In case of Creamed Ground Beef, the lid material appeared to have more difficulties to move the product and an increase in seal wrinkles was observed at lower fill weights (=more material has to be moved to equilibrate the forces). Tests with a placeble product that was not completely submersed in a liquid, resulted in even more seal wrinkles, because the lid material was not able to move any material toward the flange.

To avoid seal wrinkles caused by the vacuum, one should ensure that the solids in the tray are submerged in adequate liquid that can be pushed by lid material towards the flange of the tray. This will avoid that the lid is being pulled sharply around the flange and cause wrinkles. Even if the product is submerged in the liquid, seal wrinkles might still occur if the tray has an inadequate fill weight and thus excessive headspace volume which requires a high vacuum and a significant larger pull on the lid to equilibrate the pressures after the vacuum has been released.

Increased fill weights is the first line of action that can be taken to prevent seal wrinkles caused by the vacuum release. Preferable the increased fill weight is accomplished by increasing the liquid portion, not the solids portion. Increased fill weight might however become a problem in an indexing vacuum sealer as the product might slosh into the seal area and thus cause contamination. Continuos

motion sealers such as the one at the CORANET Demo facility had no problems dealing with higher fill weights.

The US Army Natick Soldier Center has evaluated higher residual gas levels and made recommendations to increase the maximum allowable level. This relaxation in specification limit will have a significant effect on the vacuum that needs to be pulled, resulting in an increase of maximum throughput rate and reduction in seal defects caused by vacuum wrinkles.

3.6.1.3.3. Internal Pressure

This specification reads:

Internal pressure resistance shall be determined by pressurizing the container without protective sleeve while restrained between two rigid plates. There shall be a minimum clearance of 1/8 inch between the bottom surface of the top plate and the top surface of the tray flange (with attached lid). A four-seal tester (designed to pressurize filled container by use of a hypodermic needle through the container wall or lid) shall be used and all four seals tested simultaneously. It may also be necessary to restrain the tray body during the test within either a wood or metal base, such that excessive deflection of the tray does not render a false lid failure.

Pressure shall be applied gradually until 20 psig pressure is reached. The 20 psig pressure shall be held constant for 30 seconds and then released. The container then shall be examined for separation or yield of the heat seals. Any rupture of the container or evidence of any seal separation greater than 1/16 inch or seal separation that reduces the closure seal width to less than 1/16 inch shall be considered a test failure.

The first part of the specification is difficult to implement or to verify due to the nature of a semi flexible container which does not has not an exact defined height. Nor is it easy to determine the distance between flange and the top plate during the pressure test.

The test system used in this project consisted out of a Raque Heat Seal carrier with a plate on either side. The tray was therefore supported around the perimeter avoiding stresses in the lid material. The carrier has also a support rim under the flange. The distance from this rim to the top plate was 0.20 inches with rubber gasket and 0.22 inches without rubber gasket which appears to satisfy the specification.

Meeting the internal pressure specification has not been a problem. The seals that were applied were significantly stronger that is required by this specification.

4. Appendix

4.1. Technical Working Paper #213 "Heat Penetration Studies of Pork Sausage in Brine in Polymeric Tray"

4.2. Technical Working Paper #214 " Heat Penetration Studies of Creamed Ground Beef in Polymeric Tray"

4.3. Technical Working Paper #215 "Economic Modeling and Analysis of the Manufacturing Cost Polymeric Tray"

4.4. Technical Working Paper #216 "Heat Penetration Studies of Creamed Ground Beef in Polymeric Tray, Part II"

4.5. Technical Working Paper #217 "Filling & Sealing Studies of Pork Sausage in Polymeric Tray"

4.6. Technical Working Paper #218 "Filling & Sealing Studies of Creamed Ground Beef in Polymeric Tray"

4.7. Production Summary

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Heat Penetration Studies

of

Pork Sausage in Brine in Polymeric Tray

Technical Working Paper (TWP-213)

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Introduction:

Since the inception of the Tray Pack Ration, the product has been packaged in a heavy metal tray shaped can with a double seamed metal lid and processed in non rotary, batch retort systems. Due to the declining supplier base for the metal tray can and lid and various problems with the interior coating of the cans, an alternative package was developed utilizing a polymeric tray body and a laminated foil and polymer lidstock. The change over to this particular container has a significant impact on the number of containers that can be processed in each retort batch. A larger foot print of the container flange and the requirement that the weight of each container needs to be supported by a racking mechanism rather than by stacking the containers on top of each other reduces the capacity approximately 33%.

The impact of reduction of the batch capacity could be offset if the process cycle time could be reduced by the same amount. This project addresses the main issues involved in heat penetration and the impact of process and product parameters on the required process time.

Objective:

Conduct an experimental designed process study to determine the impact of selected packaging and process variables on the required retort cycle time to yield commercial sterile product.

Product and Package Description:

Pork Sausage Links in Brine is the product that was used in this study and complied with the Contract Technical Requirement dated January 11, 2000 with the exception that the water was used instead of brine.

The sausage links were manufactured by ASE Deli/Foodservice Company, St. Charles, IL. and are the same as used by current producers of "Pork Sausage Links in Brine" for Combat Feed Program. The supplier precooked the sausage links in order to avoid excessive weight loss during the retort process and each weighs approximately 20 grams before retorting and 17 grams after retorting. The sausage dimensions are approximately 3 " long and 1/2 to 3/4" in diameter. Each tray was filled with 72 sausage links, which were placed in two layers, each layer containing three rows of 12 sausages.

The trays used in this experiment were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

Process Description:

The trays were manually filled with sausage links and a thermocouple was placed in the middle of one sausage link, which was placed in the geometric center of the tray. The thermocouples used for the heat penetration study were manufactured by Ecklund-Harrison Technology, Ft. Myers, FL. and are identified as Needle Type thermocouple (4-3/4") type CNL. The tray was placed in the sealing carriers of the Raque Heat Sealer before a pre-weighed amount of water was added to the tray to ensure that the net weight target of 90 oz was met. The tray was sealed at a speed of approximately 8 trays/min. while seal conditions were maintained at 412 F for 2.0 seconds. The vacuum condition was a variable in this study and was controlled by a vacuum timer that opened a vacuum valve for a preset duration. A vacuum time of 1.0 second resulted in an approximate vacuum of 20" Hg in the sealing chamber, yielding trays that had a pre-retort residual gas level of less then 175 cc. A vacuum time of 0.2 seconds resulted in an approximate vacuum of 10" Hg in the sealing chamber, yielding trays that had a pre-retort residual gas level of approximately 350 cc.

Twelve sealed trays with thermocouples were loaded in the front cage of a Stock 1100, four cage Rotomat, using polymeric tray racks specifically designed for this tray. The trays were placed in layers 4 through 9 (two cans per layer). The remaining rack pockets were filled with ballast trays (trays filled with water). The other three cages of the retort were filled with ballast boxes. The polymeric tray racks used in this study were manufactured by Stock America, Grafton, WI and are identified as "7333A". The design features of this rack allowed the trays to be loaded either "face up" or "face down", and the trays are locked into the pocket so that they can be rotated during the retort process without creating abrasion defects. Four retort programs were developed and used in this study. Two programs were designed for a static process. Program #20 processed the tray "up-side-down". Program #21 processed the tray "side ways" to enhance the water flow between the containers (water flow is from top to

bottom in this type retort). Two other programs were designed for a rotational process. Program #22 rotated the tray at a speed of 5 rpm while Program #23 rotated the trays at a speed of 15 rpm. All retort programs used the same temperature and pressure profile. The temperature of the retort was set at 254 F during the Come-Up Phase (S2) and at 252 F during the Hold Phase (S3). Copies of the retort programs can be found in the Appendix I.

The heat penetration data was collected during the process via a system supplied by Ellab Inc, Copenhagen DN. The main components of the system were a 16-channel slip ring assembly, a Analog/Digital converter (CMC) and Ellab CMC software, which had the ability to calculate the F_0 values on-line. The data was analyzed using Ellab's "Eval Basic" software, version 1.20.

The heating phase of the retort process was terminated after all thermocouples had reached an F_0 value of greater or equal to 6.0 min. The cooling phase was terminated after all thermocouples indicated a temperature lower or equal to 120 F.

Full Factorial Experimental Design:

A full factorial design was adopted to investigate the effect of vacuum applied during sealing, rotation speed or retort position. Post Retort Residual Gas and the required Cooking Time (CT) of the product were measured/calculated as response variables.

Static Mode:

Parameters	Levels		Response
Retort position	Horizontal (Program 20)	Vertical (Program 21)	Residual Gas & CT (Cook Time)
Vacuum applied	20" (targeting 150 cc residual gas)	10" (targeting 350 cc residual gas)	

Rotational Mode:

Parameters	Levels		Response
Rotation speed, rpm	5 (Program 22)	15 (Program 23)	Residual Gas & CT (Cook Time)
Vacuum applied	20" (targeting 150 cc residual gas)	10" (targeting 350 cc residual gas)	

The total number of experiments required to determine the main effects and interactions for the above two factors was 4 ($=2^2$) for each mode. Each experiment would contain 12 trays with thermocouples and each experiment would be repeated at least once.

Data Analysis

Each tray was analyzed for post-retort residual gas level. This measurement was performed by opening the tray below water and capturing the "free air" in an inverted graduate cylinder. This post-retort residual gas data was the used for statistical analysis.

Using Ball's heat penetration assumptions, each thermocouple lead data was analyzed for the typical heating factors [1] such as j_h, f_h, x_{bh}, f_2. These heating factors were then used to calculate the required Cook Time to reach a Lethality of F_0= 6.0 min, using a Retort Temperature of 250 F and an Initial Product Temperature of 40 F. The Cook Time variable was then used for statistical analysis. The analysis was divided according to the retort operating modes (Static and Rotational Mode). All statistical analysis was based on the outputs from SAS software, SAS Institute Inc. and / or STATGRAPHICS Plus 5.o, Statistical Graphics Corp. The procedures used in the analysis were General Linear Model (GLM), Multifactor ANOVA, and the Univariate procedures.

Refinement of Data:

The analysis procedure started by refining the raw data by removing the outliers through a two-stage refinement process. The first stage removed the outliers based on the Residual Gas Model.
Observations with absolute standardized residual values (based on Residual Gas model) greater than 2 were removed from the data file.

> **Note:** Outliers due to residual gas might have been caused by variation during the sealing process, either due to a sticking valve or a leaking seal chamber. It was deemed prudent to

remove these outliers in order to minimize the impact of excessive variation in residual gas on subsequent analysis.

During the second stage, removing outliers based on the Cook Time model further refined the output from the first stage. The same criteria was used to discard observation with absolute standardized residual values (based on the Cook Time model) greater than 2.

Note: The exact location of the thermocouple within the sausage can have a significant effect on the heat penetration rate. Outliers in the Cook Time model might have been caused by shifting of the product during packaging and retort loading, causing an improperly located thermocouple. It was deemed prudent to remove these outliers in order to minimize the impact of incorrect located thermo couples.

The refined data was then used for subsequent analysis of variance and is reported in the following section. The analysis for the two retort modes (static and rotation) will be discussed separately.

Note: It should be noted that none of the conclusions reached in the analysis would have been reversed if the outliers had not been removed

Static Mode

Residual Gas Analysis:

The data was first analyzed for post retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Program and Vacuum was also significant at 99% confidence level, indicating the means for the different programs and vacuums are not equal.
- The interaction between Program and Vacuum was not significant.

Multiple comparison test (Tukey Test) was used to compare between two retort position and residual gas. The test indicated, as expected, that the vacuum applied during sealing had a significant impact on the residual gas level inside the tray after retorting. However, the test also indicated (at 0.05 significance level) that the post retort Residual Gas value is significantly effected by the retort position. The residual gas level was significantly higher when the product was processed in a vertical position retort position (C) , (Program 21). Because the trays were filled and sealed in a random manor, it is assumed that there would have been no significant difference between pre-retort residual gas levels inside the tray under the same vacuum conditions. It is therefore hypothesized that less air is "consumed" by, or more air expelled from the product during a vertical retort process when more product is immersed in the brine and less product is exposed the "headspace" inside the can.

Tukey Grouping	Mean	N	Program
A	276.7	67	21
B	231.1	50	20

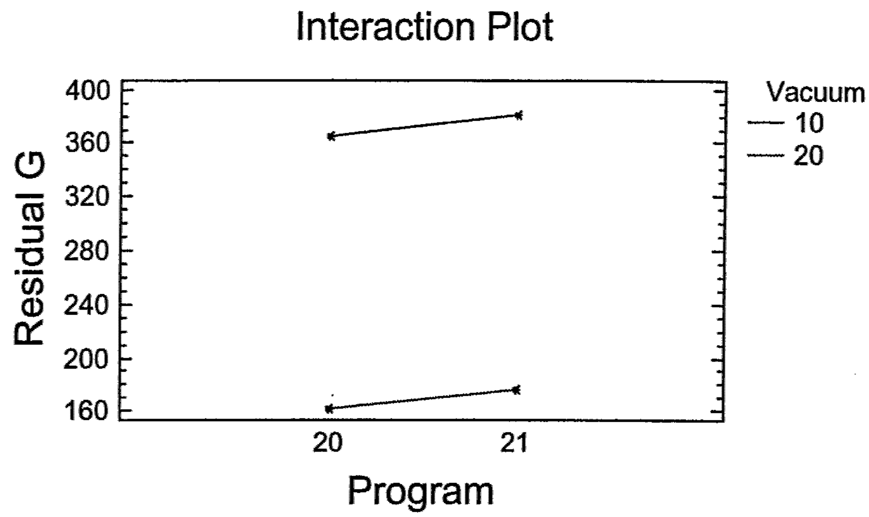
*Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Vacuum
A	375.3	50	10"
B	169.1	67	20"

*Means with the same letter are not significantly different.

Means Analysis per Treatment:

Retort Program	Level of Vacuum	N	Residual Gas			
			R-Square CV	Mean	SD	CV
20	20"	33	0.947	162.0	25.0	0.15
20	10"	17	0.095	365.2	22.2	0.06
21	20"	34		176.1	22.7	0.13
21	10"	33		380.5	26.8	0.07



Cook Time Analysis:

The refined data was then analyzed for Cook Time using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Cooking Time).
- The F-test for Program and Vacuum were also significant at 99% confidence level, indicating the means for the different programs and vacuums are not equal.
- The interaction between Program and Vacuum was not significant.

Multiple comparison test (Tukey Test) was used to compare between the different levels of retort position and residual gas. The output from the test (at 0.05 significance level) indicated that we have a lower CT value (faster heating) when the tray was processed vertical in the retort, (Program 21), and/or sealed under a 20" vacuum (~150 cc).

Tukey Grouping	Mean	N	Program
A	32.10	50	20
B	26.28	67	21

*Means with the same letter are not significantly different.

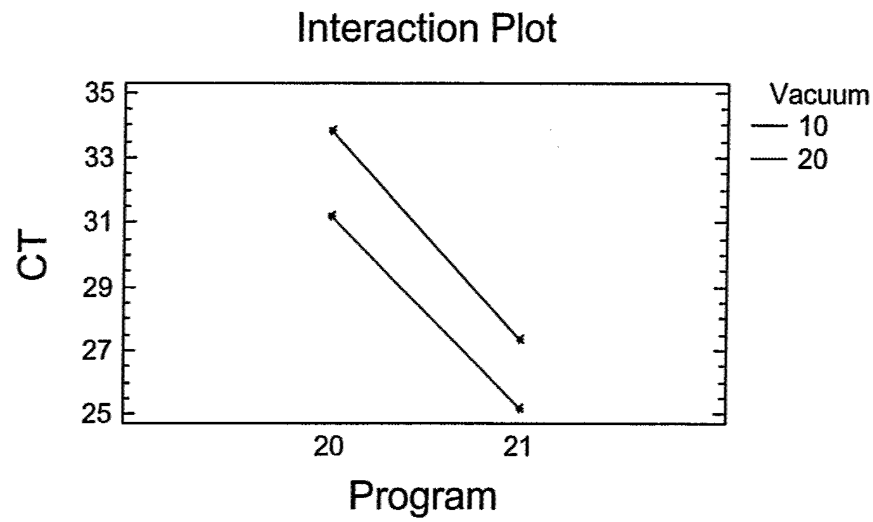
Tukey Grouping	Mean	N	Vacuum
A	29.57	50	10"
B	28.17	67	20"

*Means with the same letter are not significantly different.

The data was then analyzed for the mean value per treatment (combination of program and vacuum). As one can see from the table below and from the accompanying graph that program 20 with a low vacuum level results in the longest Cook Time while program 21 (vertical) with a high vacuum level results in the shortest Cook Time. The hypothesis is that the vertical process enhances the water flow between the containers and improves the heat transfer rate from the heating media into the container. This increased external heat transfer is especially important for fast heating products such as Pork Sausage Links in Brine, but might be less significant in slow heating products were the overall heat transfer rate is determined by the internal heat transfer rate of the tray.

Means Analysis per Treatment:

Level Of Program	Level Of Vacuum	N	CT			
			R-Square CV	Mean	SD	CV
20	20"	33	0.78	31.21	1.64	0.053
20	10"	17	0.058	33.85	2.11	0.062
21	20"	34		25.23	1.38	0.055
21	10"	33		27.36	1.74	0.063

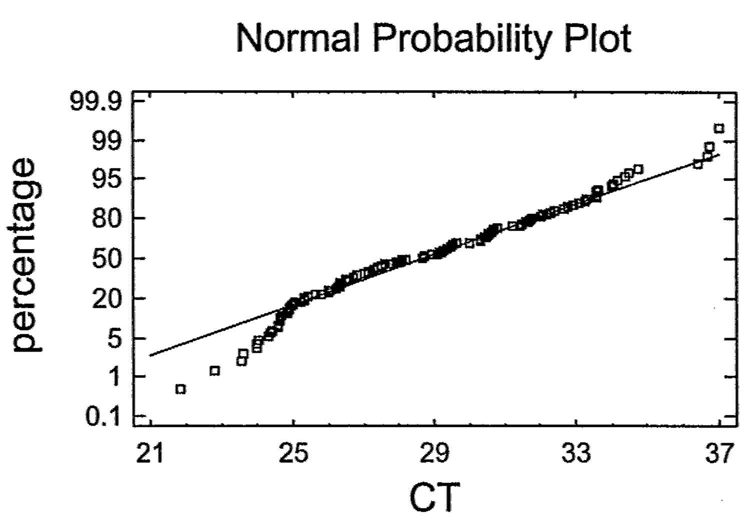


Model Assessment:

The R-Square value=0.78 in the ANOVA Table is evidence of a good fit is provided by the model. This value indicates that 78% of the variability in CT can be explained when retort position and residual gas are used as independent variables.

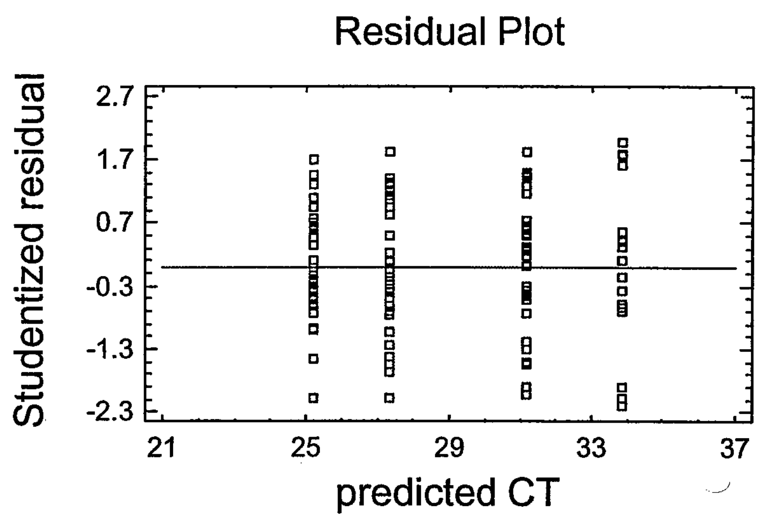
Accessing Normality:

The large value of 0.9665 for Shapiro-Wilk test and Normal Probability Plot all support the assumption of normality. This means that it is appropriate to use ANOVA analysis.



Accessing of Equality of Variance:

The Plot of Studentized Residual * Predicted CT shows a plot of residuals vs. predicted values of CT . Based on this plot, there is no strong evidence for unequal variances and for outliers. This means that our methodology for refining the data was successful.



Location of Tray Analysis:

Multiple Range Tests for Cook Time by Location (Appendix-II) revealed no statistically significant differences between any pair of means at the 95.0% confidence level. The method used to discriminate among the means is Tukey's honestly significant difference (HSD) procedure.

Dynamic Mode:

Residual Gas Analysis:

The data was first analyzed for post retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-III. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Program and Vacuum was also significant at 99% confidence level, indicating the means for the different programs and vacuums are not equal.
- The interaction between Program and Vacuum was significant at 99% confidence.

Multiple comparison test (Tukey Test) was used to compare between the two retort rotational speeds and residual gas. The test indicated, as expected, that the vacuum applied during sealing had a significant impact on the residual gas level inside the tray after retorting. However, the test also indicated (at 0.05 significance level) that the post retort Residual Gas value was significantly affected by the retort rotational speed. The residual gas level was significantly higher when the product was processed at rotational speed of 5 rpm , (Program 22). Because the trays were filled and sealed in a random manor, it can be assumed that there would be no significant difference between pre-retort residual gas levels inside the tray when the same vacuum condition was used. It is therefore hypothesized that less air is "consumed", or more air expelled by the product during a slow rotational retort process (5 rpm).

Tukey Grouping	Mean	N	Program
A	224.4	42	22
B	185.0	53	23

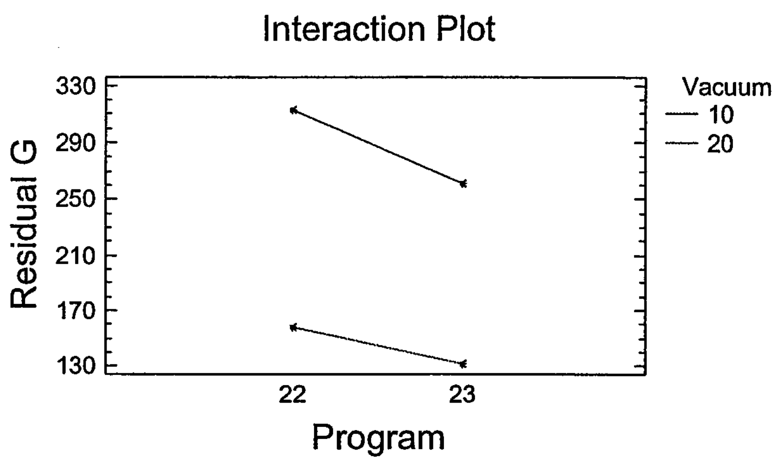
*Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Vacuum
A	284.3	40	10”
B	142.9	55	20”

*Means with the same letter are not significantly different.

Means Analysis per Treatment:

Retort Program	Level Of Vacuum	N	Residual Gas			
			R-Square CV	Mean	SD	CV
22	20”	24	0.942	157.9	15.9	0.10
22	10”	18	0.090	313.1	28.0	0.089
23	20”	31		131.3	14.5	0.11
23	10”	22		260.8	15.1	0.058



Cook Time Analysis:

The refined data was then analyzed for Cook Time using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-III. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Cooking Time).
- The F-test for Program and Vacuum are also significant at 99% confidence level, indicating the means for the different programs and vacuums are not equal.
- The interaction between Program and Vacuum is significant at 95% confidence.

Multiple comparison test (Tukey Test) was used to compare between the different levels of rotational speed and residual gas. The output from the test (at 0.05 significance level) indicated that we have a

lower CT value (faster heating) when the tray was processes at a rotational speed of 15 rpm, (Program 23), and/or sealed under a 20" vacuum (~ 150cc).

Tukey Grouping	Mean	N	Program
A	29.32	42	22
B	24.70	53	23

*Means with the same letter are not significantly different.

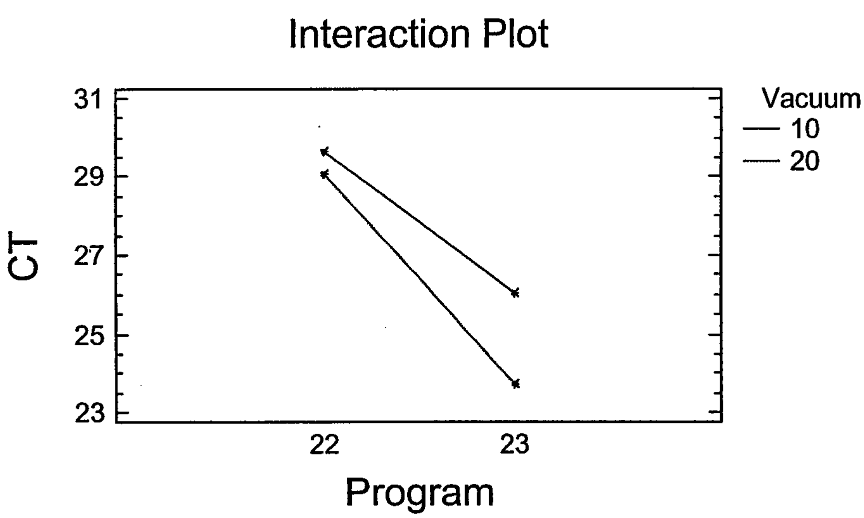
Tukey Grouping	Mean	N	Vacuum
A	27.66	40	10"
B	26.07	55	20"

*Means with the same letter are not significantly different.

The data was then analyzed for the mean value per treatment (combination of program and vacuum). Program 22 with a low vacuum level (10" and ~350 cc res. gas) resulted in the longer Cook Time, while program 23 (15 rpm) with a high vacuum level (20" and 150 cc res. gas) resulted in the shortest Cook Time. This negative impact of higher levels of residual gas on heating rate was unexpected. Typically, higher residual gas levels assist in the flow of material inside the tray. It is hypothesized that the overall heat transfer is determined by the external heat transfer into the container and the natural convective flow of the brine is sufficient in transferring the heat throughout the tray. Forced convective flows inside the tray due to the rotation have no benefits in enhancing heat transfer in this particular type product. In fact, it is hypothesized that the additional air inside the tray appears to actually slow down the heat transfer from the container walls into the product.

Means Analysis per Treatment:

Level Of Program	Level Of Vacuum	N	CT			
			R-Square CV	Mean	SD	CV
22	150	24	0.64	29.07	1.34	0.046
22	350	18	0.070	29.65	1.76	0.059
23	150	31		23.75	2.06	0.087
23	350	22		26.03	2.18	0.084



Location of Tray Analysis:

Multiple Range Tests for Cook Time by Location (Appendix-III) revealed no statistically significant differences between any pair of means at the 95.0% confidence level. The method used to discriminate among the means is Tukey's honestly significant difference (HSD) procedure.

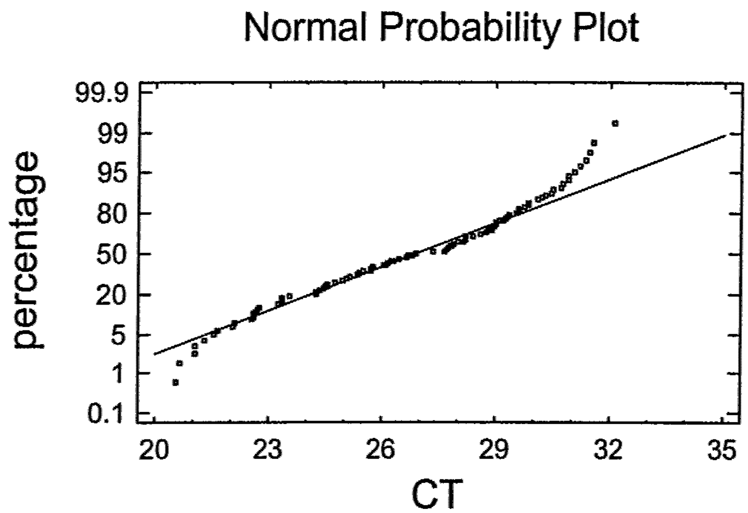
Model Assessment:

The fit of the model:

Evidence of a good fit is provided by the R-Square value= 0. 64. Nearly 64% of the variability in CT has been explained when rotational speed and residual gas are used as independent variables.

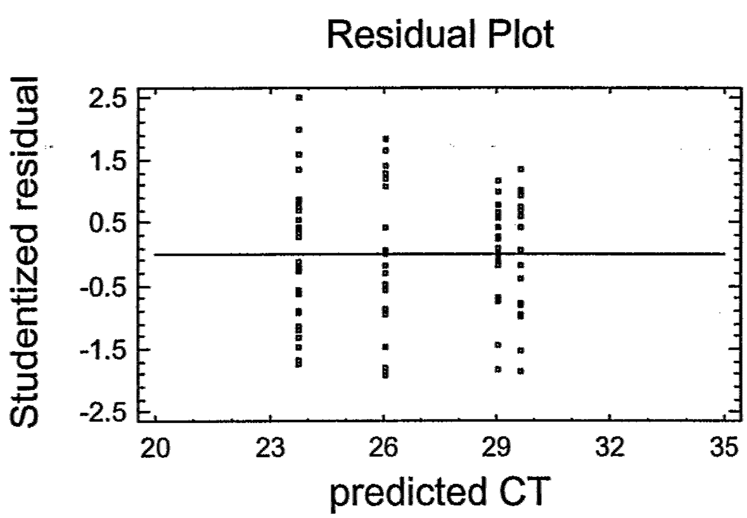
Accessing Normality:

The large value of 0.960 for Shapiro-Wilk test and Normal Probability Plot all support an assumption of normality.



Accessing of Equality of Variance:

The Plot of Studentized Residual * Predicted CT shows a plot of residuals vs. predicted values of CT . Based on this plot, there is no strong evidence for unequal variances and for outliers.



Conclusions:

The statistical results (based on the full factorial baseline experiments) indicate that:

- Post Retort Residual Gas is affected by the retort process
- Location of the tray within the crate seems to be not significant, indicating good heating uniformity throughout the crate and no serious cold spots in any of the four programs.
- The calculated cook time based on the heating factors is significantly impacted by the vacuum condition/residual gas inside the tray and by the retort position/speed.
- The slowest packaging/retort condition is a low vacuum pack (10") processed in static horizontal position.
- The fastest packaging/retort condition is a high vacuum pack (20"), processed in a high-speed rotational process (15 rpm).
- Outliers have no effect on the above conclusions.

References:

1. Stumbo, C. R. (1973), Thermobacteriology in Food Processing, 2nd edition. Orlando: Academic Press, Inc.
2. Hicks, C. R., and Turner, Jr., K. V. (1999), Fundamental Concepts in the Design of Experiments, 5th edition. New York: Oxford University Press, Inc.
3. Dean, A. and Voss, D. (1999), Design and Analysis of Experiments, New York: Springer-Verlag, Inc.
4. SAS/STAT (1990), User's Guide, Version 6, 4th ed., SAS Institute Inc., Cary, NC, USA.
5. STATGRAPHICS Plus (2000), A Manugistics Product, Version 5, Manugistics, Inc., Maryland, USA.

Attachments:

Appendix I: Retort Programs

Appendix II: Data Analysis Static Retort Mode

Appendix III: Data Analysis Rotational Retort Mode

Appendix I

Retort Programs

ICON 2000 Stock America
Retort Program Print

Program # 020 STP1022_DOWN Product # 000000000020 Cont. Size:Poly Tray
Program last changed: 12:03:47 PM 10/16/2000

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

#20

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	0	0	0	0	0
Position:	A	C	C	C	C	C	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 021 STP1022_SIDE Product # 000000000021 Cont. Size:Poly Tray
Program last changed: 12:06:30 PM 10/16/2000

#21

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	0	0	0	0	0
Position:	A	B	B	B	B	B	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 022 STP1022_5RPM Product # 000000000022 Cont. Size:Poly Tray
Program last changed: 12:09:29 PM 10/16/2000

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

#22

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	5	5	5	5	0
Position:	A	A	A	A	A	A	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 023 STP1022_15RP Product # 000000000023 Cont. Size:Poly Tray
Program last changed: 12:11:35 PM 10/16/2000

#23

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	15	15	15	15	0
Position:	A	A	A	A	A	A	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

Appendix II

Data Analysis Static Retort Mode

Refined Data

Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	CT
I001019A	20	20	1	6	188	0.95	19.54	33.6
I001019A	20	20	3	6	180	0.86	17.85	30.68
I001019A	20	20	4	8	182	0.81	18.14	30.57
I001019A	20	20	5	5	180	0.59	22.28	32.43
I001019A	20	20	6	9	188	0.33	28.41	31.47
I001019A	20	20	7	8	187	0.76	19.81	32.03
I001019A	20	20	8	4	152	0.86	20.69	34.16
I001019A	20	20	9	7	168	0.43	24.96	31.75
I001019A	20	20	10	4	145	0.89	16.11	28.74
I001019A	20	20	15	5	174	0.41	22.47	29.08
I001019A	20	20	16	7	175	0.38	24.99	30.43
I001024A	20	10	1	9	390	0.53	23.84	32.93
I001024A	20	10	3	4	380	0.55	24.58	34.05
I001024A	20	10	5	6	400	0.41	29.12	34.74
I001024A	20	10	6	8	345	0.31	28.54	30.79
I001024A	20	10	7	7	350	0.58	24.34	34.37
I001024A	20	10	8	5	355	0.52	21.39	30.33
I001024A	20	10	9	4	400	0.34	30.78	33.6
I001024A	20	10	15	5	370	0.51	25.91	34.5
I001031A	20	20	1	9	154	0.31	28.29	30.61
I001031A	20	20	3	5	176	0.36	24.26	29.26
I001031A	20	20	4	8	132	0.59	21.94	32.08
I001031A	20	20	5	4	206	0.42	23.66	30.36
I001031A	20	20	6	7	160	0.25	28.21	27.93
I001031A	20	20	7	6	112	0.63	22.34	33.13
I001031A	20	20	8	5	194	0.48	23.39	31.48
I001031A	20	20	9	4	192	0.45	21.06	28.69
I001031A	20	20	10	7	178	0.36	26.07	30.71
I001031A	20	20	13	8	148	0.78	21	33.65
I001031A	20	20	15	9	138	0.3	30.4	31.67
I001031A	20	20	16	6	180	0.51	21.25	30.02
I001107A	20	10	1	7	315	0.51	24.01	32.69
I001107A	20	10	3	8	355	0.43	23.58	30.53
I001107A	20	10	4	7	375	0.58	26.67	36.7
I001107A	20	10	5	5	345	0.54	23.51	32.8
I001107A	20	10	6	6	350	0.37	28.87	33.24
I001107A	20	10	7	9	360	0.49	28.83	36.73
I001107A	20	10	10	5	380	0.67	24.84	36.43
I001107A	20	10	13	9	360	0.53	24.98	34.04
I001107A	20	10	16	8	380	0.61	26.37	36.99
I001114A	20	20	1	9	168	0.79	19.76	32.3
I001114A	20	20	3	6	150	0.71	19.63	31.24
I001114A	20	20	4	6	156	0.53	22.61	31.72
I001114A	20	20	5	4	110	0.77	21.03	33.56
I001114A	20	20	6	5	146	0.66	17.38	28.1
I001114A	20	20	7	5	162	0.94	18.49	32.19
I001114A	20	20	8	7	132	0.81	19.02	31.63
I001114A	20	20	9	7	148	0.71	19.17	30.71
I001114A	20	20	13	9	176	0.64	19.77	30.5
I001114A	20	20	16	8	108	0.51	24.68	33.33

Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	CT
I001019C	21	20	1	6	202	0.7	14.26	24.88
I001019C	21	20	3	8	200	0.75	12.26	22.83
I001019C	21	20	4	9	196	0.76	13.63	24.61
I001019C	21	20	5	5	192	0.65	14.37	24.55
I001019C	21	20	6	5	206	0.69	14.12	24.62
I001019C	21	20	7	7	206	0.68	11.86	21.83
I001019C	21	20	8	4	194	0.68	15.19	25.79
I001019C	21	20	9	9	186	0.76	14.1	25.19
I001019C	21	20	10	7	210	0.75	12.9	23.63
I001019C	21	20	13	6	174	0.68	14.52	25.01
I001019C	21	20	15	8	188	0.7	13.17	23.57
I001019C	21	20	16	4	208	0.59	16.69	26.5
I001024B	21	10	1	9	360	0.37	19.61	25.66
I001024B	21	10	3	4	335	0.37	18.64	24.83
I001024B	21	10	4	6	390	0.48	17.01	25.33
I001024B	21	10	5	5	375	0.33	20.04	25.04
I001024B	21	10	6	5	370	0.28	21.47	24.64
I001024B	21	10	7	7	350	0.37	20.49	26.33
I001024B	21	10	8	6	410	0.39	19.58	26.09
I001024B	21	10	9	4	370	0.57	16.66	26.22
I001024B	21	10	10	7	365	0.43	19.32	26.68
I001024B	21	10	13	9	355	0.56	17.81	27.31
I001024B	21	10	15	8	360	0.45	16.09	23.96
I001024B	21	10	16	8	420	0.56	15.96	25.34
I001031B	21	20	1	6	144	0.76	15.01	26.31
I001031B	21	20	3	7	182	0.63	14.55	24.56
I001031B	21	20	4	8	188	0.87	13.05	24.66
I001031B	21	20	5	5	130	0.81	14.84	26.51
I001031B	21	20	6	7	196	0.7	14.71	25.41
I001031B	21	20	7	8	162	0.84	12.92	24.29
I001031B	21	20	8	4	140	0.74	13.6	24.42
I001031B	21	20	9	4	202	0.73	13.32	24
I001031B	21	20	10	6	182	0.83	13.39	24.83
I001031B	21	20	16	9	194	0.74	13.98	24.88
I001107B	21	10	1	9	410	0.67	16.56	27.28
I001107B	21	10	3	7	415	0.51	18.04	26.82
I001107B	21	10	5	5	350	0.55	19.52	28.95
I001107B	21	10	6	6	370	0.62	17.5	27.76
I001107B	21	10	7	8	395	0.68	15.66	26.34
I001107B	21	10	8	4	350	0.69	16.24	27.12
I001107B	21	10	9	4	345	0.67	16.76	27.5
I001107B	21	10	10	5	350	0.59	17.64	27.53
I001107B	21	10	13	9	370	0.47	18.44	26.57
I001107B	21	10	16	8	360	0.66	16.43	27.02
I001206A	21	10	1	9	370	0.86	16.29	28.73
I001206A	21	10	3	7	405	0.81	17.31	29.56
I001206A	21	10	4	7	395	0.74	17.53	29.14
I001206A	21	10	5	6	395	0.78	17.39	29.37
I001206A	21	10	6	4	390	0.77	16.5	28.2
I001206A	21	10	7	8	380	1.17	15.28	29.5
I001206A	21	10	8	5	375	0.75	17.64	29.37

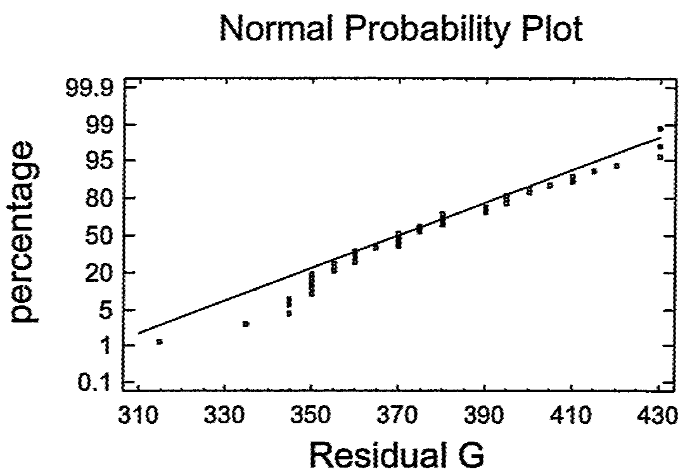
Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	CT
I001206A	21	10	9	9	380	0.78	17.26	29.21
I001206A	21	10	10	13	430	0.78	17.63	29.66
I001206A	21	10	13	8	430	1.07	15.71	29.49
I001206A	21	10	16	5	430	0.75	18.47	30.35
I001206B	21	20	1	8	160	1.06	11.8	24.03
I001206B	21	20	3	9	162	0.86	14.35	26.27
I001206B	21	20	4	6	162	0.98	14.57	27.38
I001206B	21	20	5	5	152	0.75	15.16	26.4
I001206B	21	20	6	4	152	0.68	16.25	27.03
I001206B	21	20	7	6	152	0.96	14.24	26.81
I001206B	21	20	8	5	172	0.93	15.02	27.63
I001206B	21	20	9	8	148	0.79	13.24	24.35
I001206B	21	20	10	4	166	0.9	15.48	28.02
I001206B	21	20	13	9	164	0.93	13.78	26.01
I001206B	21	20	15	7	150	0.92	13.01	24.92
I001206B	21	20	16	7	164	0.92	13.84	26.02

1. RESIDUAL GAS ANALYSIS

a.1 Probability Plot - Residual G (Vacuum=10 & first(117))

Analysis Summary

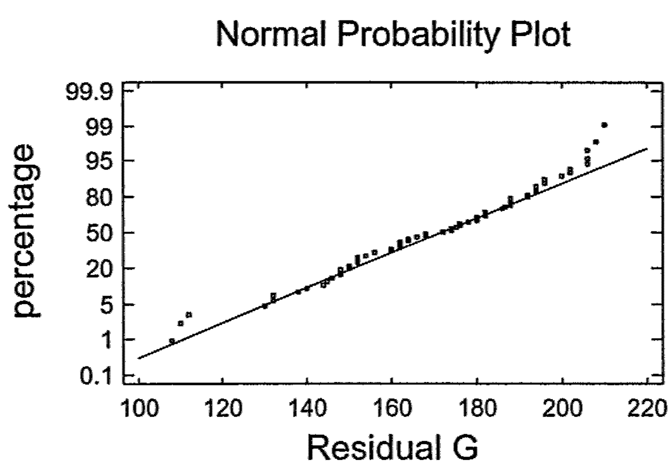
```
Data variable: Residual G
Selection variable: Vacuum=10 & first(117)
50 values ranging from 315.0 to 430.0
```



a.2 Probability Plot - Residual G (Vacuum=20 & first(117))

Analysis Summary

Data variable: Residual G
Selection variable: Vacuum=20 & first(117)
67 values ranging from 108.0 to 210.0



b. Multifactor ANOVA - Residual G (first (117))

Analysis Summary

Dependent variable: Residual G
Factors:
  Program
  Vacuum
Selection variable: first (117)
Number of complete cases: 117

Analysis of Variance

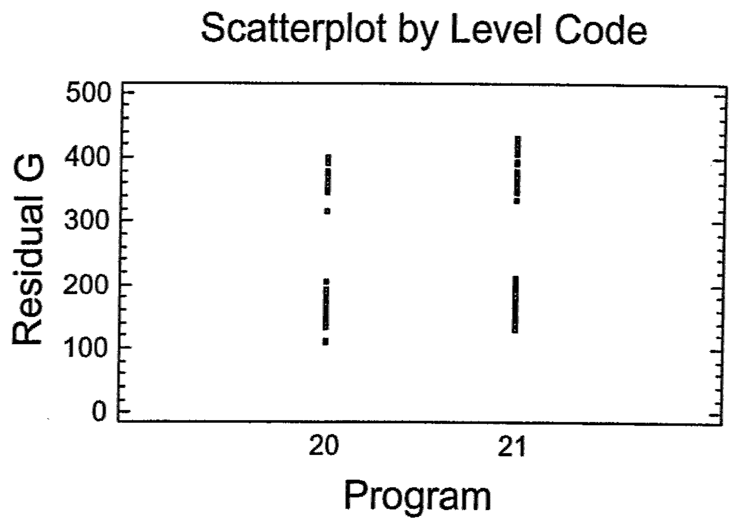
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1.22308E6	3	407694.0	678.36	0.0000
Residual	67912.6	113	600.996		
Total (Corr.)	1.29099E6	116			

R-squared = 94.7395 percent
R-squared (adjusted for d.f.) = 94.5999 percent
Standard Error of Est. = 24.5152
Mean absolute error = 20.5006
Durbin-Watson statistic = 1.69605 (P=0.0502)
Lag 1 residual autocorrelation = 0.145914

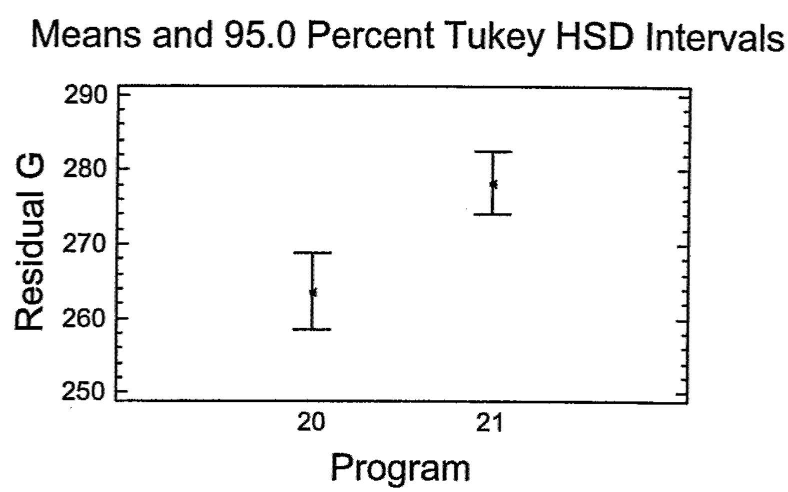
Analysis of Variance for Residual G - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	5747.98	1	5747.98	9.56	0.0025
B:Vacuum	1.11687E6	1	1.11687E6	1858.36	0.0000
INTERACTIONS					
AB	7.7108	1	7.7108	0.01	0.9100
RESIDUAL	67912.6	113	600.996		
TOTAL (CORRECTED)	1.29099E6	116			

All F-ratios are based on the residual mean square error.

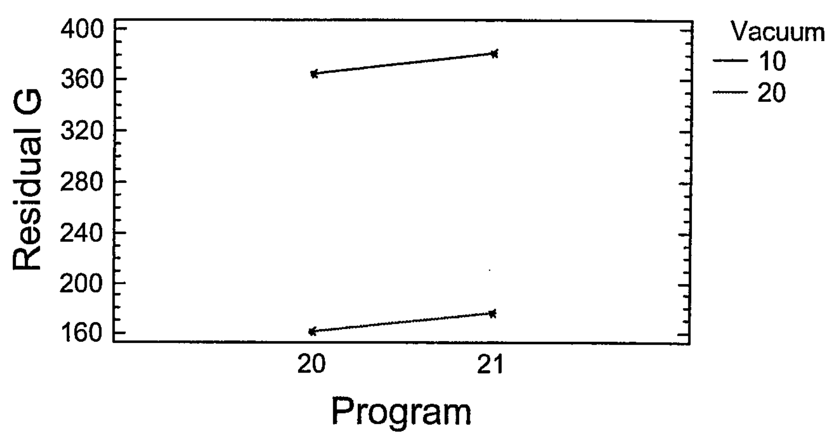


Scatterplot by Level Code
Residual G
500
400
300
200
100
0
20
21
Program

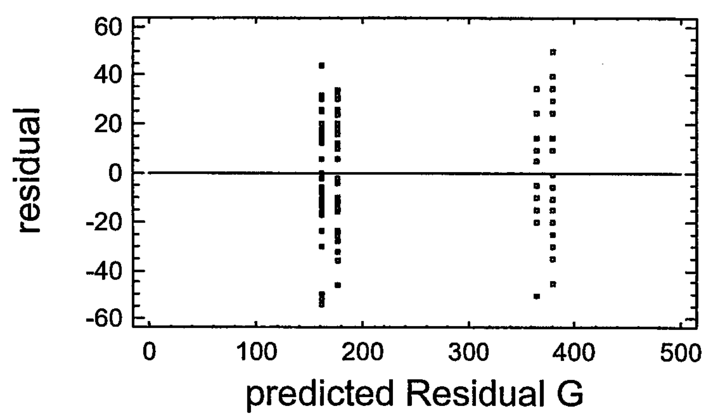


Means and 95.0 Percent Tukey HSD Intervals
Residual G
290
280
270
260
250
20
21
Program

Interaction Plot



Residual Plot for Residual G

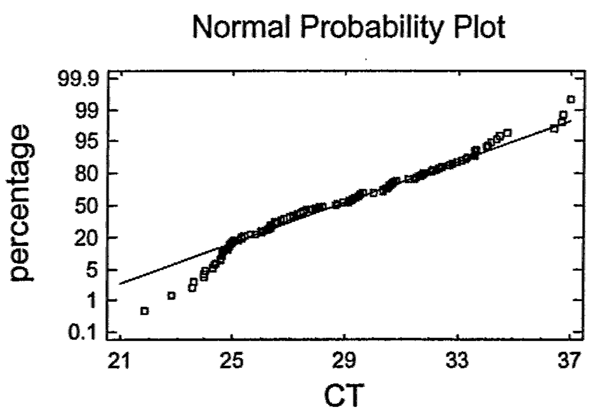


2. COOK TIME ANALYSIS

a. Probability Plot - CT (first (117))

Analysis Summary

Data variable: CT
Selection variable: first (117)
117 values ranging from 21.83 to 36.99



b. Multifactor ANOVA - CT (first (117))

Analysis Summary

Dependent variable: CT
Factors:
  Program
  Vacuum
Selection variable: first (117)
Number of complete cases: 117

Analysis of Variance

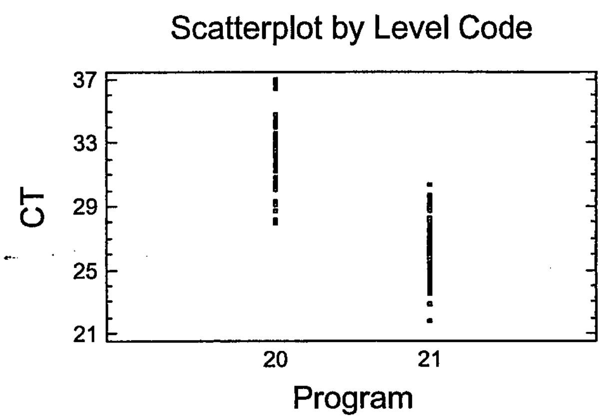
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1126.81	3	375.605	134.05	0.0000
Residual	316.62	113	2.80195		
Total (Corr.)	1443.44	116			

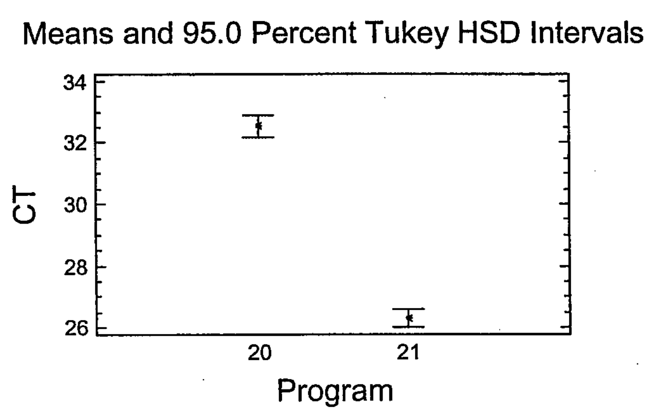
R-squared = 78.0648 percent
R-squared (adjusted for d.f.) = 77.4825 percent
Standard Error of Est. = 1.6739
Mean absolute error = 1.34034
Durbin-Watson statistic = 1.55459 (P=0.0077)
Lag 1 residual auto correlation = 0.212667

Analysis of Variance for CT - Type III Sums of Squares

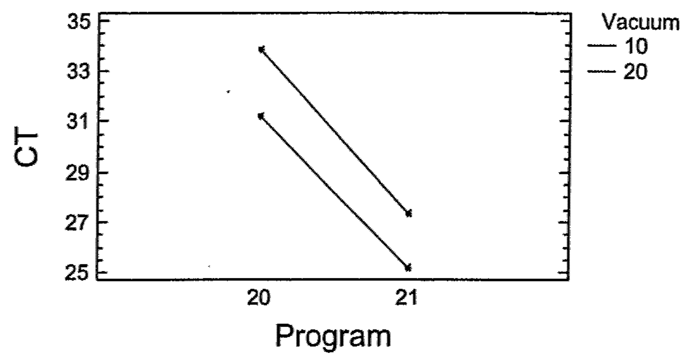
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	1044.48	1	1044.48	372.77	0.0000
B:Vacuum	153.309	1	153.309	54.71	0.0000
INTERACTIONS					
AB	1.7582	1	1.7582	0.63	0.4299
RESIDUAL	316.62	113	2.80195		
TOTAL (CORRECTED)	1443.44	116			

All F-ratios are based on the residual mean square error.

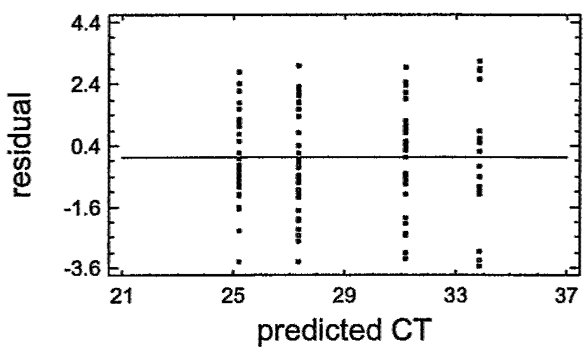




Interaction Plot



Residual Plot for CT



3. Location of Tray Analysis:

Program 20

Multiple Range Tests for CT by Location

Method: 95.0 percent Tukey HSD

Location	Count	Mean	Homogeneous Groups
5	10	31.66	X
4	7	31.88	X
7	9	31.88	X
6	8	32.2963	X
8	8	32.4963	X
9	8	32.5313	X

* denotes a statistically significant difference.
X denotes no statistically significant difference.

Program 21

Multiple Range Tests for CT by Location

Method: 95.0 percent Tukey HSD

Location	Count	Mean	Homogeneous Groups
8	12	25.4483	X
7	11	25.9	X
4	11	26.33	X
6	10	26.377	X
9	11	26.52	X
5	11	26.8718	X
13	1	29.66	X

* denotes a statistically significant difference.
X denotes no statistically significant difference.

Appendix III

Data Analysis Rotational Retort Mode

Refined Data

Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	CT
I001020A	22	20	1	8	152	0.92	17.61	30.9
I001020A	22	20	3	4	180	0.82	17.74	30.18
I001020A	22	20	4	5	148	1.06	15.31	28.89
I001020A	22	20	5	9	160	0.9	17.28	30.31
I001020A	22	20	6	7	158	1.03	15.4	28.82
I001020A	22	20	7	7	178	0.84	17.87	30.52
I001020A	22	20	8	6	168	0.95	16.59	29.83
I001020A	22	20	9	9	140	1.14	14.85	28.73
I001020A	22	20	10	8	160	0.71	17.64	28.95
I001020A	22	20	13	5	156	0.72	18.34	29.87
I001020A	22	20	15	6	150	0.86	18.27	31.2
I001020A	22	20	16	4	160	0.86	15.45	27.67
I001025A	22	10	1	8	290	0.5	18.26	26.89
I001025A	22	10	3	4	300	0.77	16.5	28.2
I001025A	22	10	4	5	335	0.84	15.74	27.88
I001025A	22	10	5	6	275	0.74	19.53	31.47
I001025A	22	10	6	5	290	0.82	18.45	31.04
I001025A	22	10	7	9	290	0.8	18.12	30.44
I001025A	22	10	8	6	280	0.73	17.42	28.91
I001025A	22	10	9	4	280	0.7	18.41	29.73
I001025A	22	10	10	7	285	0.81	18.43	30.92
I001025A	22	10	15	9	300	0.82	18.19	30.72
I001101A	22	20	1	8	150	1.06	14.45	27.71
I001101A	22	20	3	8	162	0.82	16.96	29.22
I001101A	22	20	4	7	168	0.83	17.61	30.11
I001101A	22	20	5	4	140	0.91	15.2	27.73
I001101A	22	20	6	6	202	0.91	16.65	29.59
I001101A	22	20	7	7	178	0.89	15.37	27.8
I001101A	22	20	8	4	160	0.91	16.38	29.25
I001101A	22	20	9	6	132	0.79	14.34	25.73
I001101A	22	20	10	5	150	0.79	17.07	29.08
I001101A	22	20	13	9	140	0.88	16.79	29.53
I001101A	22	20	15	5	138	0.85	14.54	26.44
I001101A	22	20	16	9	160	0.87	16.9	29.58
I001108A	22	10	3	8	350	0.89	18.19	31.37
I001108A	22	10	6	5	340	0.85	18	30.77
I001108A	22	10	7	7	325	0.83	18.77	31.53
I001108A	22	10	8	5	350	0.83	15.78	27.85
I001108A	22	10	9	4	325	0.93	15.43	28.17
I001108A	22	10	10	7	320	0.64	16	26.31
I001108A	22	10	15	8	350	0.88	16.62	29.31
I001108A	22	10	16	6	350	0.9	18.7	32.1
I001020B	23	20	1	5	130	0.83	14.85	26.68
I001020B	23	20	3	9	130	0.95	13.22	25.38
I001020B	23	20	6	4	118	0.92	14.85	27.34
I001020B	23	20	8	9	134	1.06	12.73	25.33
I001020B	23	20	13	7	112	1.01	15.05	28.21
I001020B	23	20	15	8	96	1	13.63	26.24
I001020B	23	20	16	8	160	0.95	14.17	26.65
I001025B	23	10	1	9	280	0.69	15.35	26.08

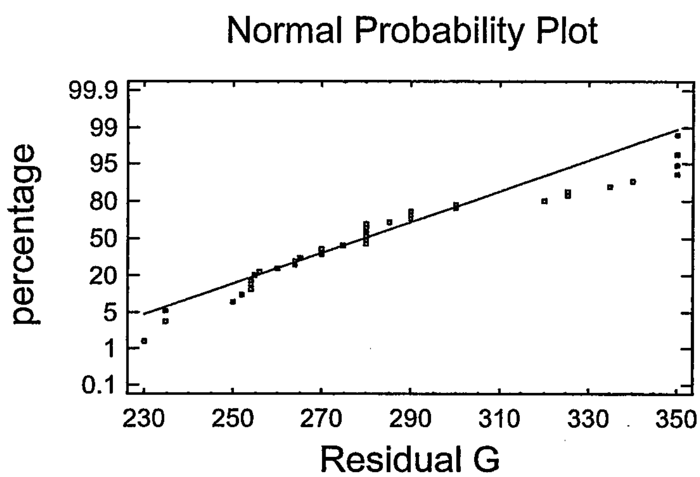
Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	CT
I001025B	23	10	4	5	235	0.74	16.89	28.38
I001025B	23	10	5	6	255	0.94	13.84	26.15
I001025B	23	10	6	6	270	0.8	16.94	29.02
I001025B	23	10	7	8	270	0.85	16.26	28.61
I001025B	23	10	8	9	270	0.98	13.32	25.7
I001025B	23	10	9	4	235	0.78	16.43	28.21
I001025B	23	10	10	5	250	0.81	17.16	29.37
I001025B	23	10	13	8	265	1.05	13.04	25.71
I001025B	23	10	15	7	280	1.01	13.43	26.03
I001025B	23	10	16	7	260	0.74	17.42	29.01
I001101B	23	20	1	6	136	1.23	9.96	22.05
I001101B	23	20	3	9	128	1.14	11.91	24.56
I001101B	23	20	4	8	160	1.03	12.43	24.76
I001101B	23	20	5	4	152	1.22	10.84	23.33
I001101B	23	20	6	7	130	0.82	11.71	22.59
I001101B	23	20	7	8	138	1.02	11.39	23.26
I001101B	23	20	8	4	128	1.11	12	24.55
I001101B	23	20	9	5	146	1.27	9.9	22.1
I001101B	23	20	10	6	138	1.11	12.36	25.06
I001101B	23	20	13	9	142	1.09	11.35	23.53
I001101B	23	20	15	5	148	1.03	12.23	24.48
I001101B	23	20	16	7	136	0.97	12.96	25.15
I001109B	23	10	1	9	256	1.21	11.49	24.25
I001109B	23	10	3	8	254	1.22	11.95	24.97
I001109B	23	10	4	7	254	1.18	10.95	23.33
I001109B	23	10	5	4	254	1.24	12.25	25.49
I001109B	23	10	6	6	280	1.25	11.99	25.15
I001109B	23	10	7	7	230	1.09	13.67	26.8
I001109B	23	10	8	5	252	1.35	10.16	22.76
I001109B	23	10	9	6	264	1.06	10.77	22.57
I001109B	23	10	10	5	264	1.25	11.51	24.44
I001109B	23	10	16	8	280	1.28	10.25	22.66
I001114B	23	20	1	7	128	1.01	10.97	22.62
I001114B	23	20	3	9	132	0.99	9.57	20.56
I001114B	23	20	4	5	142	1.02	9.56	20.67
I001114B	23	20	5	4	126	1.04	10.18	21.64
I001114B	23	20	6	6	132	0.93	10.12	21.06
I001114B	23	20	7	5	114	0.75	11.06	21.32
I001114B	23	20	8	8	132	1.18	9.75	21.55
I001114B	23	20	9	9	114	1.13	10.65	22.69
I001114B	23	20	10	4	118	1.06	12.04	24.36
I001114B	23	20	13	6	136	0.89	10.25	21.05
I001114B	23	20	15	8	130	1.02	11.47	23.37
I001114B	23	20	16	7	104	1.04	12.02	24.24

1. RESIDUAL GAS ANALYSIS

a.1 Probability Plot - Residual G (Vacuum=10 & last(95))

Analysis Summary

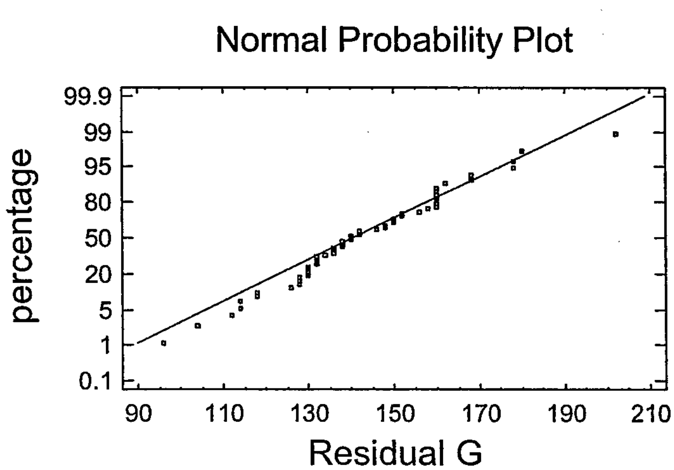
Data variable: Residual G
Selection variable: Vacuum=10 & last(95)
40 values ranging from 230.0 to 350.0



a.2 Probability Plot - Residual G (Vacuum=20 & last(95))

Analysis Summary

Data variable: Residual G
Selection variable: Vacuum=20 & last(95)
55 values ranging from 96.0 to 202.0



b. Multifactor ANOVA - Residual G (last (95))

Analysis Summary

Dependent variable: Residual G
Factors:
    Program
    Vacuum
Selection variable: last (95)
Number of complete cases: 95

Analysis of Variance

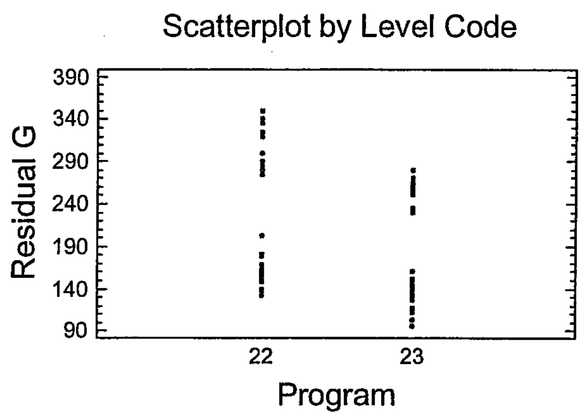
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	499727.0	3	166576.0	499.51	0.0000
Residual	30346.4	91	333.477		
Total (Corr.)	530074.0	94			

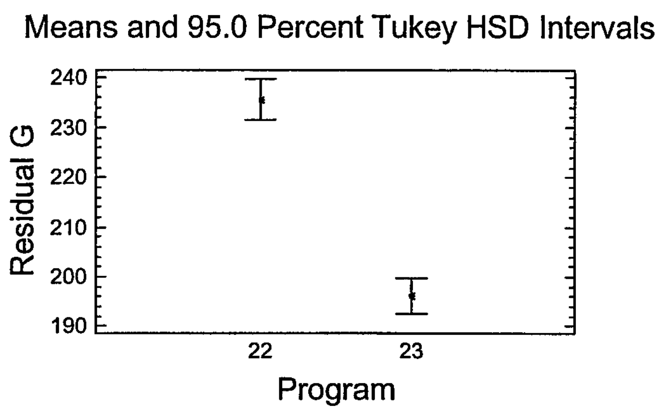
R-squared = 94.2751 percent
R-squared (adjusted for d.f.) = 94.0863 percent
Standard Error of Est. = 18.2614
Mean absolute error = 14.0198
Durbin-Watson statistic = 1.39439 (P=0.0004)
Lag 1 residual autocorrelation = 0.289959

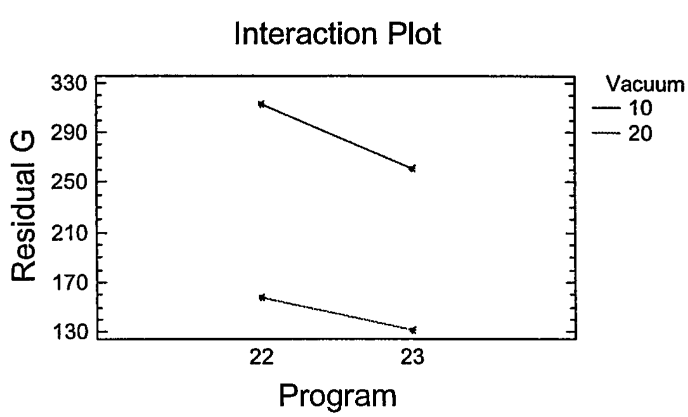
Analysis of Variance for Residual G - Type III Sums of Squares

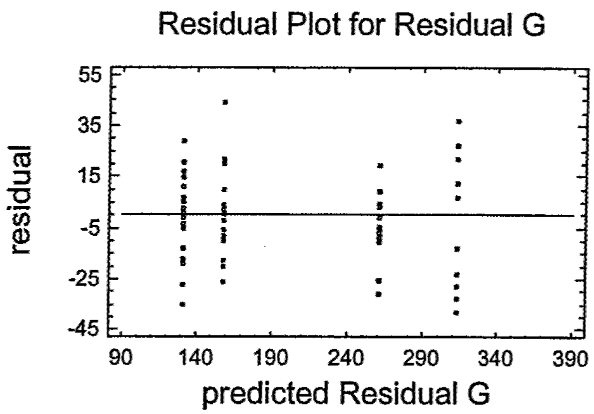
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	35553.2	1	35553.2	106.61	0.0000
B:Vacuum	463231.0	1	463231.0	1389.09	0.0000
INTERACTIONS					
AB	3749.54	1	3749.54	11.24	0.0012
RESIDUAL	30346.4	91	333.477		
TOTAL (CORRECTED)	530074.0	94			

All F-ratios are based on the residual mean square error.


Scatterplot by Level Code
390
340
290
240
190
140
90
Residual G
22
23
Program


Means and 95.0 Percent Tukey HSD Intervals
240
230
220
210
200
190
Residual G
22
23
Program


Interaction Plot
330
290
250
210
170
130
Residual G
22
23
Program
Vacuum
10
20

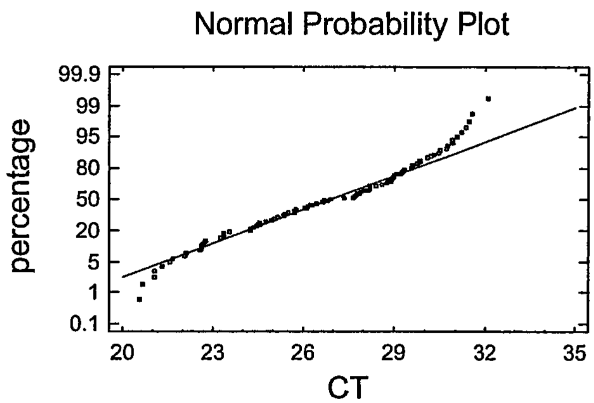

Residual Plot for Residual G
residual
55
35
15
-5
-25
-45
90
140
190
240
290
340
390
predicted Residual G

2. COOK TIME ANALYSIS

a. Probability Plot - CT (last (95))

Analysis Summary

Data variable: CT
Selection variable: last (95)
95 values ranging from 20.56 to 32.1



b. Multifactor ANOVA - CT (last (95))

Analysis Summary

Dependent variable: CT
Factors:
Program
Vacuum
Selection variable: last (95)

Number of complete cases: 95

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	569.438	3	189.813	53.77	0.0000
Residual	321.24	91	3.53011		
Total (Corr.)	890.678	94			

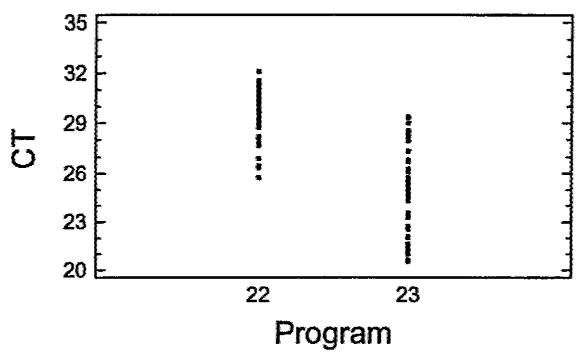
R-squared = 63.9331 percent
R-squared (adjusted for d.f.) = 62.7441 percent
Standard Error of Est. = 1.87886
Mean absolute error = 1.51245
Durbin-Watson statistic = 1.13199 (P=0.0000)
Lag 1 residual autocorrelation = 0.428418

Analysis of Variance for CT - Type III Sums of Squares

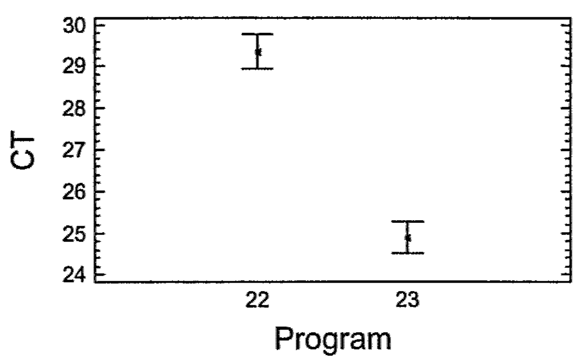
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	455.674	1	455.674	129.08	0.0000
B:Vacuum	46.5418	1	46.5418	13.18	0.0005
INTERACTIONS					
AB	16.5214	1	16.5214	4.68	0.0331
RESIDUAL	321.24	91	3.53011		
TOTAL (CORRECTED)	890.678	94			

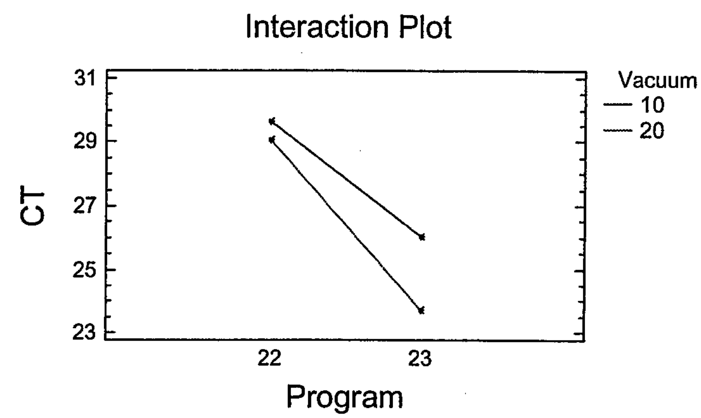
All F-ratios are based on the residual mean square error.

Scatterplot by Level Code

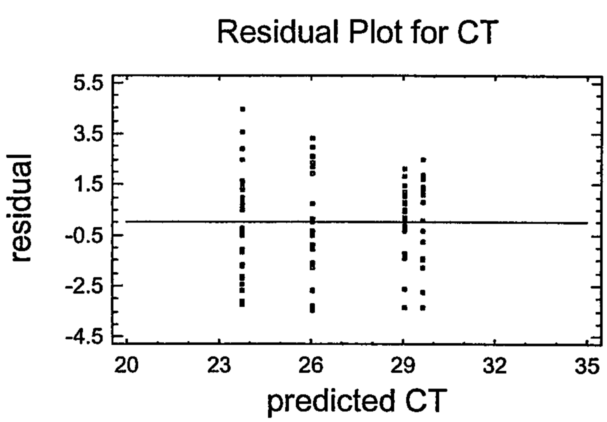


Means and 95.0 Percent Tukey HSD Intervals





Interaction Plot
Vacuum
10
20
31
29
27
25
23
CT
22
23
Program



Residual Plot for CT
5.5
3.5
1.5
-0.5
-2.5
-4.5
residual
20
23
26
29
32
35
predicted CT

3. Location of Tray Analysis

Program 22

Multiple Range Tests for CT by Location

Method: 95.0 percent Tukey HSD

Location	Count	Mean	Homogeneous Groups
4	7	28.7043	X
5	8	28.9775	X
8	7	29.1929	X
7	7	29.43	X
6	7	29.8329	X
9	6	29.885	X

* denotes a statistically significant difference.
X denotes no statistically significant difference.

Program 23

Multiple Range Tests for CT by Location

Method: 95.0 percent Tukey HSD

Location	Count	Mean	Homogeneous Groups
6	8	24.0138	X
9	9	24.2311	X
5	9	24.4667	X
8	10	24.778	X
7	9	25.3311	X
4	8	25.3637	X

* denotes a statistically significant difference.
X denotes no statistically significant difference.

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Heat Penetration Studies

of

Creamed Ground Beef in Polymeric Tray

Technical Working Paper (TWP-214)

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Date

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Table of Content

1 Introduction

Since the inception of the Tray Pack Ration, the product has been packaged in a heavy metal tray shaped can with a double seamed metal lid and processed in non rotary, batch retort systems. Due to the declining supplier base for the metal tray can and lid and various problems with the interior coating of the cans, an alternative package was developed utilizing a polymeric tray body with a laminated foil and polymer lidstock. The change over to this particular container has a significant impact on the number of containers that can be processed in each retort batch. A larger foot print of the container flange and the requirement that the weight of each container needs to be supported by a racking mechanism rather than by stacking the containers on top of each other reduces the capacity approximately 33%.

The reduction in batch capacity can be offset, if the process cycle time can be reduced by the same percentage. This project investigates the impact of selected process and product parameters on the heat penetration rate of the product and the required process time to render the product commercial sterile.

2 Objective

Conduct an experimental designed process study to determine the impact of selected packaging and process variables on the required retort cycle time to yield commercial sterile product.

3 Product and Package Description

Creamed Ground Beef, the product that was used in this study, complies with the Contract Technical Requirement dated January 11, 2000.

The precooked ground beef used for this study was manufactured by St James Gourmet, Farmingdate NY. The ground beef was partial precooked, frozen and packed in cryovac bags by the supplier for easier handling. The ground beef was re-blanched at the FMT facility to avoid excessive weight loss during the retort process and thinning of the sauce. Also, the precooking/blanching process removed excessive fat and juices, which otherwise might yield an unacceptable product.

The cream sauce was made according to the recommended formula in the product specification with the exception that the starch quantity was reduced from 6% to 5.5%. The three main ingredients: "Starch", "Dry Cream" and "Shortening" were manufactured by respectively National Starch, Bridgewater NJ (Purity W), Quality Ingredients, Burnsville MN (Quali-Cream 7211) and Kerry Inc, Beloit WI (NDX-112 V, Item No. I1529).

The trays used in this experiment were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

4 Process Description:

The cream sauce was made in a jacketed kettle, equipped with high speed mixer and scrape surface agitator using the following procedure:

1) Mix required quantity of starch in small quantity of cold water and mix vigorously to form a thin slurry.
2) Add remaining quantity of cold water to kettle.
3) Add Dry Cream to kettle and mix vigorously (speed setting: 2) till all dissolved.
4) Add remaining ingredients (except starch slurry) to kettle and mix while heating kettle till product reaches 180 F to 190 F. Use high heat setting
5) Add starch slurry and the final mixture should be heated to 180 F to 190 F and held at this temperature for 5 minutes. (Use low heat setting once 180 F is reached)
6) If product needs to be refrigerated, cool product to 90 F and pump into buckets. Label buckets with material ID and Lot Number. Place product in refrigerator.

After the precooked ground beef was blanched at out facility to remove excessive fat and juices from the ground beef, the ground beef was drained and mixed with the refrigerated cream sauce at a ration of 32 oz of ground beef to 60 oz of cream sauce.

The trays were filled to a net weight of 92 oz. The trays intended for heat penetration studies were equipped with a thermocouple that was placed in the middle of the tray and held in place by a 1.5" diameter spacer disk which was placed near the end of the thermocouple. The thermocouples used for the heat penetration study were manufactured by Ecklund-Harrison technology, Ft.Myers FL. and are identified as Needle Type thermocouple (4-3/4") type CNL.

The filled trays were placed in the sealing carriers of the Raque Heat Sealer and sealed at a speed of approximately 8 trays/min. while seal conditions were maintained at 412 F for 2.0 seconds. The vacuum condition was a variable in this study. and was controlled by a vacuum timer that opened a vacuum valve for a preset duration. A vacuum time of 1.0 seconds resulted in an approximate vacuum of 20" Hg in the sealing chamber, yielding trays that had a pre-retort residual gas level of less then 175 cc. A vacuum time of 0.17 seconds resulted in an approximate vacuum of 10" Hg in the sealing chamber, yielding trays that had a pre-retort residual gas level of approximately 350 cc.

Twelve sealed trays with thermocouples were loaded "face up" in the front cage of a Stock 1100, four cage Rotomat, using polymeric tray racks specifically designed for this tray. The trays were placed in layers 4 through 9 (two cans per layer). Several additional trays without thermocouples were also placed within these layers and retorted to yield samples for post process product evaluation. All remaining rack pockets were filled with ballast trays (trays filled with water). The other three cages of the retort were filled with ballast boxes. The polymeric tray racks used in this study were manufactured by Stock America, Grafton, WI and are identified as "7333A". The design features of this rack allowed the trays to be loaded either "face up" or "face down", and the tray are locked into the pocket so that they can be rotated during the retort process without creating abrasion defects.

Four retort programs were developed and used in this study. Two programs were designed for a static process. Program #20 processed the tray "up-side-down". Program #21 processed the tray "side ways" to enhance the water flow between the containers (water flow is from top to bottom in this type retort). Two other programs were designed for a rotational process. Program #22 rotated the tray at a speed of 5 rpm while Program #23 rotated the trays at a speed of 15 rpm. All retort programs used the same temperature and pressure profile. The temperature of the retort was set at 254 F during the Come Up Phase (S2) and at 252 F during the Hold Phase (S3). Copies of the retort programs can be found in the Appendix I.

The heat penetration data was collected during the process via a system supplied by Ellab Inc, Copenhagen DN. The main components of the system were a 16 channel slip ring assembly, a Analog/Digital converter (CMC) and Ellab CMC software, which had the ability to calculate the F_0 values on-line. The data was analyzed using Ellab's "Eval Basic" software, version 1.20.

The heating phase of the retort process was terminated after all thermocouples had reached an F_0 value of greater or equal to 6.0 min. The cooling phase was terminated after all thermocouples indicated a temperature lower or equal to 120 F.

5 Full Factorial Experimental Design:

A full factorial design was adopted to investigate the effect of vacuum applied during sealing and retort rotation speed or crate position. Post Retort Residual Gas, Post Retort Product Consistency and the required Cooking Time (CT) of the product were measured/calculated as response variables. The analysis was divided according to the retort operating modes (Static and Dynamic Mode).

Static Mode:

Parameters	**Levels**		**Response**
Retort position	Horizontal (Program 20)	Vertical (Program 21)	Residual Gas, Product Consistency & CT (Cook Time)
Vacuum applied	20" (targeting 150 cc residual gas)	10" (targeting 350 cc residual gas)	

Dynamic Mode:

Parameters	**Levels**		**Response**
Rotation speed, rpm	5 (Program 22)	15 (Program 23)	Residual Gas, Product Consistency & CT (Cook Time)
Vacuum applied	20" (targeting 150 cc residual gas)	10" (targeting 350 cc residual gas)	

The total number of experiments required to determine the main effects and interactions for the above two factors was 4 (=2^2) for each mode. Each experiment would contain 12 trays with thermocouples and a few additional trays without thermocouples. Each experiment would be repeated at least once.

6 Data Analysis

Using Ball's heat penetration assumptions, each thermocouple lead data was analyzed for the typical heating factors[1] such as *jh, fh, xbh, f2*. These heating factors were then used to calculate the required Cook Time to reach a Lethality of F_0= 6.0 min, using a Retort Temperature of 250 F and an Initial Product Temperature of 80 F. The Cook Time variable was then used for statistical analysis. The analysis was divided according to the retort operating modes (Static and Rotational Mode).

Each tray with a thermocouples was also analyzed for post-retort residual gas level. This measurement was performed by opening the tray below water and capturing the "free air" in an inverted graduate cylinder. This post-retort residual gas data was the used for statistical analysis.

One of the trays without thermocouple was analyzed for product consistency. This measurement was done by heating the product, draining the sauce from the ground beef in a #7 sieve and measuring the consistency in a Bostwick Consistometer. Due to the limited data, data is reported "as is" and no statistical analysis could be performed.

All statistical analysis was based on the outputs from SAS software[4], SAS Institute Inc and StatGraphics version 5.0[5]. The statistical procedures used in the analysis were General Linear Model (GLM), Multifactor ANOVA, and the Univariate procedures.

6.1 Refinement of Data

The analysis procedure started by refining the raw data by removing the outliers through two-stage refinement process. The first stage removed the outliers based on residual gas model. Observations with absolute standardized residual values (based on Residual Gas model) greater than 2 were removed from the data file.

Note: Outliers due to residual gas might have been caused by variation during the sealing process, either due to a sticking valve or a leaking seal chamber. It was deemed prudent to remove these outliers in order to minimize the impact of excessive variation in residual gas on subsequent analysis.

During the second stage, removing outliers based on the Cook Time model further refined the output from the first stage. The same criteria was used to discard observation with absolute standardized residual values (based on the Cook Time model) greater than 2.

Note: The exact location of the thermocouple within container can have a significant effect on the heat penetration rate. Outliers in the Cook Time model might have been caused by shifting of spacer disk during packaging and retort loading, causing an improperly located thermocouple. It was deemed prudent to remove these outliers in order to minimize the impact of incorrect located thermocouples.

The refined data was then used for subsequent analysis of variance and is reported in the following section. The analysis for the two retort modes (static and rotation) will be discussed separately.

Note: It should be noted that none of the conclusions reached in the analysis would have been reversed if the outliers would not have been removed.

6.2 Static Mode

6.2.1 Residual Gas Analysis:

The data was first analyzed for post retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Program and Vacuum was also significant at 99% confidence level, indicating the means for the different programs and vacuums are not equal.
- The interaction between Program and Vacuum was significant at 95% confidence level.

Multiple comparison test (Tukey Test) was used to compare between the two retort positions and the two levels of vacuum. The test indicated, as expected, that the vacuum applied during sealing had a significant impact on the residual gas level inside the tray after retorting. However, the test also indicated (at 0.05 significance level) that the post retort Residual Gas value was significantly affected by the retort position. The residual gas level was significantly higher when the product was processed in a vertical position, retort position (C) - (Program 21). Because the trays were filled and sealed in a random manor, it can be assumed that there would have been no significant difference between pre-retort residual gas levels inside the tray under the same vacuum conditions. It is therefore hypothesized that less air is "consumed" by, or more air expelled from the product during a vertical retort process when less product is exposed to the "headspace" inside the can.

Tukey Grouping	Mean	N	Program
A	244.3	44	21
B	199.3	42	20

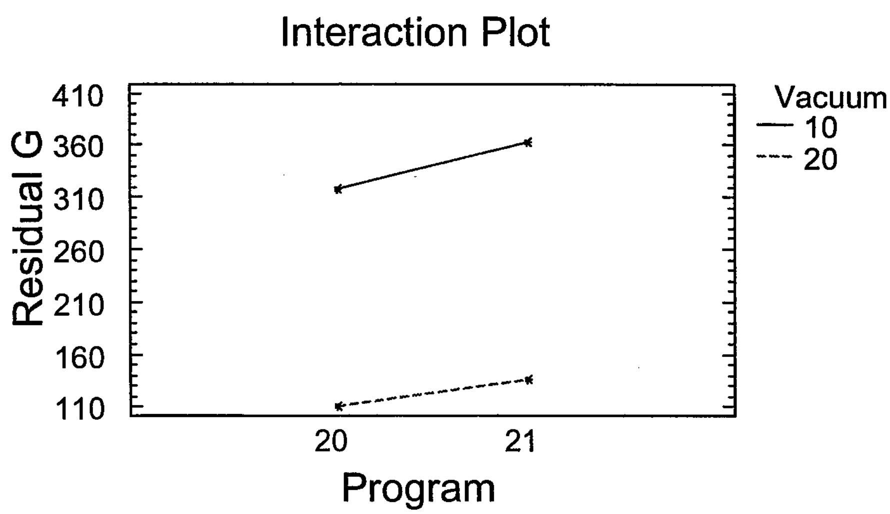
*Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Vacuum
A	341.5	39	10"
B	123.4	47	20"

*Means with the same letter are not significantly different.

Means Analysis per Treatment:

Retort Program	Level of Vacuum	N	Residual Gas			
			R-Square CV	Mean	SD	CV
20	20"	24	0.969	111	14	0.13
20	10"	18	0.089	316.9	23.6	0.07
21	20"	23		136.3	17.4	0.13
21	10"	21		362.6	24.4	0.07



6.2.2 Cook Time Analysis

The refined data was then analyzed for Cook Time using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Cooking Time).
- No significant difference between the means of programs 20 and 21.
- The F-test for Vacuum was significant at 99% confidence level, indicating the means at the different vacuum levels are not equal.
- The interaction between Program and Vacuum was significant at 99% confidence level.

Multiple comparison test (Tukey Test) was used to compare between the different levels of vacuum. The output from the test (at 0.05 significance level) indicated that we have a lower CT value (faster heating) when the tray was processed sealed under a 20" vacuum (~150 cc).

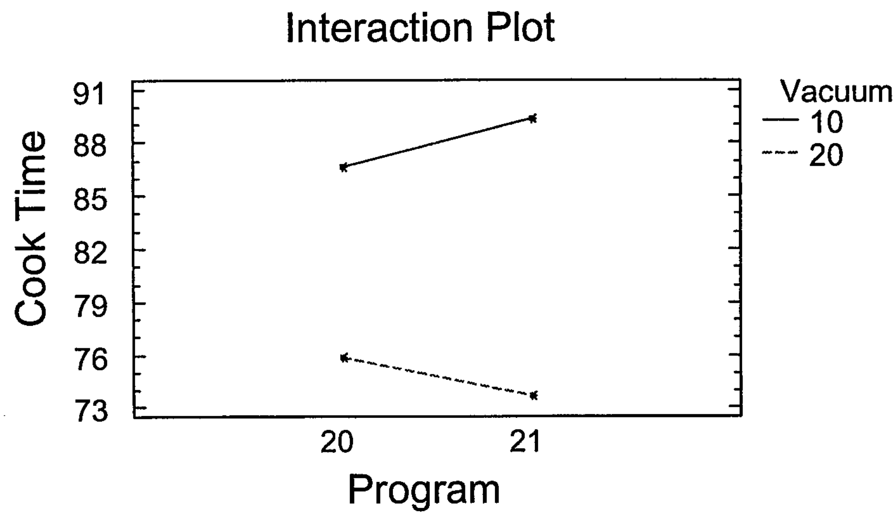
Tukey Grouping	Mean	N	Vacuum
A	88	39	10"
B	74.7	47	20"

*Means with the same letter are not significantly different.

The data was then analyzed for the mean value per treatment (combination of program and vacuum). As one can see from the table below and from the accompanying graph that program 21 with a low vacuum level (10") results in the longest Cook Time while program 21 (vertical) with a high vacuum level (20") results in the shortest Cook Time.

Means Analysis per Treatment:

Level Of Program	Level Of Vacuum	N	CT			
			R-Square CV	Mean	SD	CV
20	20"	24	0. 92	75.79	1.90	0.025
20	10"	18	0.026	86.6	2.77	0.031
21	20"	23		73.66	1.99	0.027
21	10"	21		89.35	1.61	0.018

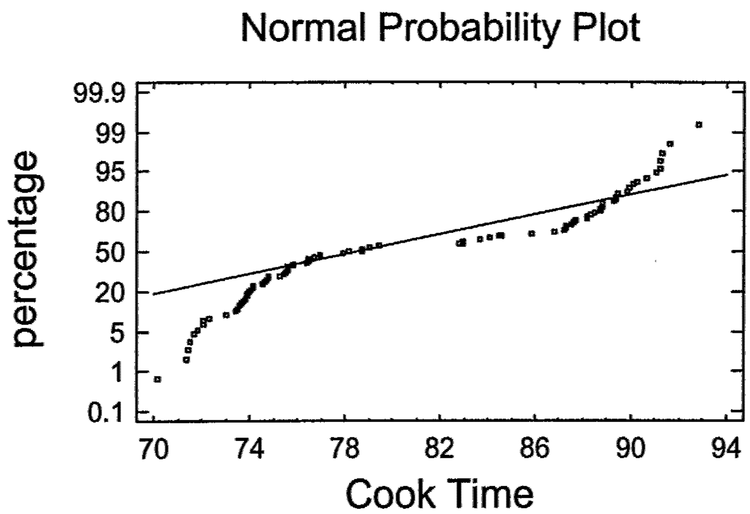


Model Assessment:

The R-Square value=0.92 in the ANOVA Table is evidence of a good fit is provided by the model. This value indicates that 92% of the variability in CT can be explained when retort position and vacuum level are used as independent variables.

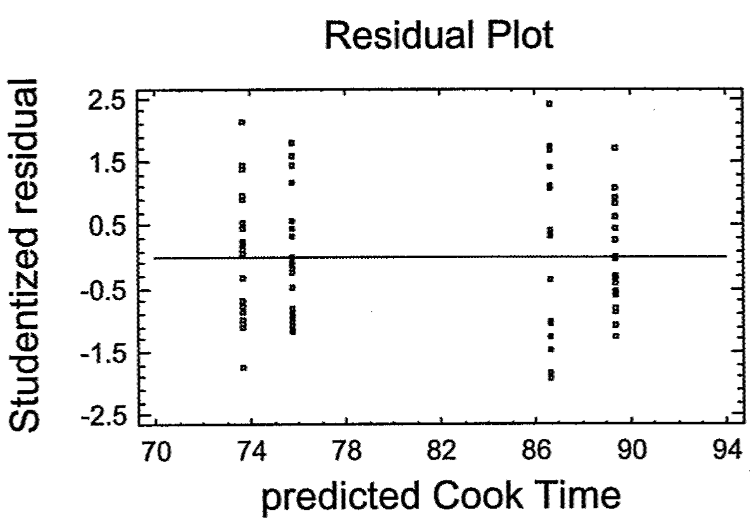
Accessing Normality:

The large value of 0.87 for Shapiro-Wilk test and Normal Probability Plot all support the assumption of normality. This means that it is appropriate to use ANOVA analysis.



Accessing of Equality of Variance:

The Plot of Studentized Residual * Predicted CT shows a plot of residuals vs. predicted values of CT . Based on this plot, there is no strong evidence for unequal variances and for outliers. This means that our methodology for refining the data was successful.



6.2.3 Location of Tray Analysis:

Multiple Range Tests for Cook Time by Location within the retort crate (Appendix-II) revealed no statistically significant differences between any pair of means at the 95.0% confidence level. The method used to discriminate among the means is Tukey's honestly significant difference (HSD) procedure.

6.3 Dynamic Mode:

6.3.1 Residual Gas Analysis:

The data was first analyzed for post retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-III. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Program was not significant at 95% confidence level.
- The F-test for Vacuum was significant at 99% confidence level, indicating the means for the different vacuums are not equal.
- The interaction between Program and Vacuum was not significant at 95% confidence level.

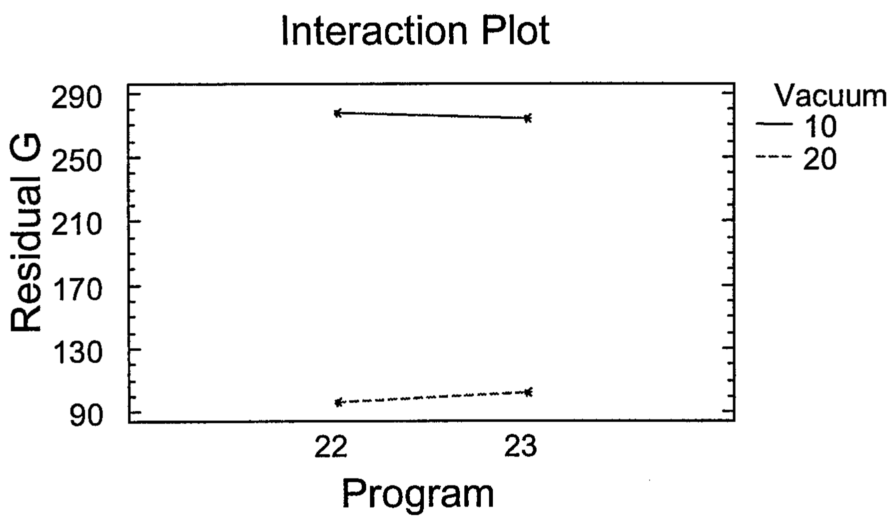
Multiple comparison test (Tukey Test) was used to compare between the different levels of vacuum. The test indicated, as expected, that the vacuum applied during sealing had a significant impact on the residual gas level inside the tray after retorting.

Tukey Grouping	Mean	N	Vacuum
A	275.7	46	10”
B	100	53	20”

*Means with the same letter are not significantly different.

Means Analysis per Treatment:

Retort Program	Level Of Vacuum	N	Residual Gas			
			R-Square CV	Mean	SD	CV
22	20”	22	0.973	97	11	0.11
22	10”	23	0.081	278	16.97	0.06
23	20”	31		102.2	13.95	0.14
23	10”	23		273.5	16.26	0.06



6.3.2 Cook Time Analysis:

The refined data was then analyzed for Cook Time using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-III. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Cooking Time).
- The F-test for Program and Vacuum were also significant at 99% confidence level, indicating the means for the different programs and vacuums are not equal.
- The interaction between Program and Vacuum was significant at 95% confidence.

Multiple comparison test (Tukey Test) was used to compare between the different levels of rotational speed and vacuum. The output from the test (at 0.05 significance level) indicated that we have a lower CT value (faster heating) when the tray was processes at a rotational speed of 15 rpm, (Program 23), and/or sealed under a 10" vacuum (~ 350cc).

Tukey Grouping	Mean	N	Program
A	57.4	45	22
B	49.3	54	23

*Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Vacuum
A	57.55	53	20"
B	47.70	46	10"

*Means with the same letter are not significantly different.

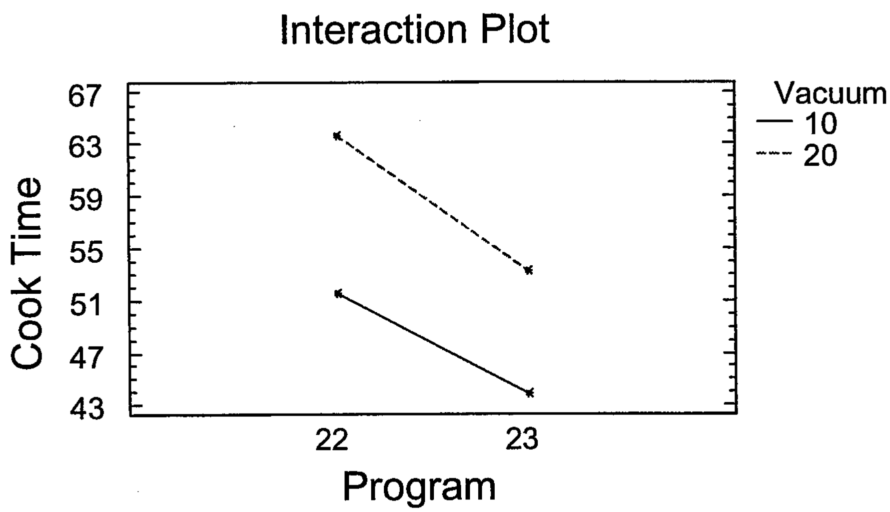
The data was then analyzed for the mean value per treatment (combination of program and vacuum). Program 22 with a high vacuum level (20" and ~150 cc res. gas) resulted in the longer Cook Time, while program 23 (15 rpm) with a low vacuum level (10" and 350 cc res. gas) resulted in the shortest Cook Time.

This positive impact of higher levels of residual gas on heating rate is well documented by many researchers in this type product. The "gas bubble" moves through the sauce while the tray is rotated, causing the sauce to flow. The so-called "forced convective flows" inside the tray due to the moving gas bubble enhances the heat transfer rate inside the tray.

Note: It should be pointed out that this phenomena could not be substantiated in a fast heating product such as "Pork Sausage Links in Brine" (TWP213) [6], where the heat trransfer rate seemed to be limited by the external heat transfer rate. It might also not occur in very viscous products such as "Mashed Potatoes" when the gas bubble is not able to move through the product.

Means Analysis per Treatment:

Level Of Program	Level Of Vacuum	N	CT			
			R-Square CV	Mean	SD	CV
22	20”	22	0.86	63.59	3.01	0.047
22	10”	23	0.05	51.49	2.53	0.049
23	20”	31		53.26	2.59	0.048
23	10”	23		43.92	2.66	0.06



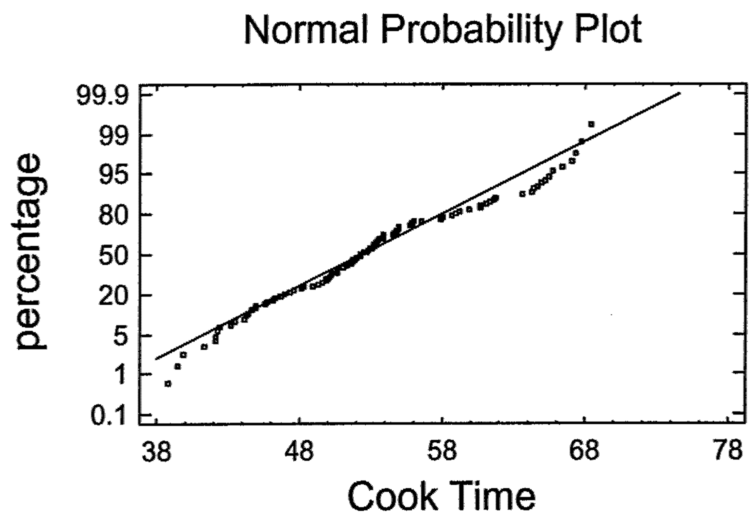
Model Assessment:

The fit of the model:

Evidence of a good fit is provided by the R-Square value= 0. 86. Nearly 86% of the variability in CT has been explained when rotational speed and vacuum level are used as independent variables.

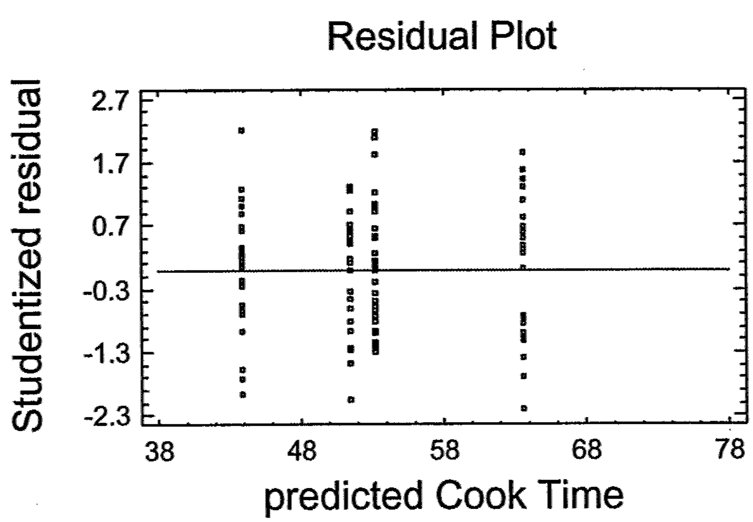
Accessing Normality:

The large value of 0.97 for Shapiro-Wilk test and Normal Probability Plot all support an assumption of normality.



Accessing of Equality of Variance:

The Plot of Studentized Residual * Predicted CT shows a plot of residuals vs. predicted values of CT . Based on this plot, there is no strong evidence for unequal variances and for outliers. This means that our methodology for refining the data was successful.



6.3.3 Location of Tray Analysis:

Multiple Range Tests for Cook Time by Location (Appendix-III) revealed no statistically significant differences between any pair of means at the 95.0% confidence level. The method used to discriminate among the means is Tukey's honestly significant difference (HSD) procedure.

6.4 Comparisons of Static and Dynamic Retort Processing

6.4.1 Residual Gas

It was concluded that there was no significant impact of the program mode (program 22 and 23) on the post retort residual gas. However, there was a very significant reduction in post retort residual gas level when one switches from static (program 20/21) to dynamic (program 22/23) retort processing. It is hypothesized that less air is "consumed" by, or more air expelled from the product during a static retort process when less product is exposed to the "headspace" inside the can.

Program	Vacuum [inches Hg]	Post Process Residual Gas [cc]
Static	10	341.5
	20	123.4
Dynamic	10	275.7
	20	100.0

6.4.2 Product Color

The sauce color darkened significantly during rotational retort processing. However, samples submitted to The US Army Natick Soldier Center, Group Ration Team at Natick were still rated as "acceptable". The darkening of the sauce color can be compensated by using "titanium di-oxide" in the sauce formulation

6.4.3 Product Consistency Data

Rotational retort processing had a significant impact on the consistency of the product after retorting as can be seen in the table below. Consistency is measured by the distance the sauce travels during a 10 second time frame. Therefore rotational retort process leads to a thinner sauce. Samples submitted to The US Army Natick Soldier Center, Group Ration Team at Natick were rated as "acceptable"

Program	Vacuum [inches Hg]	Consistency [cm/10 sec]
20	10	4.3
	20	4.4
21	10	4.2
	20	4.7
22	10	7.3
	20	6.7
23	10	6.4
	20	7.1

7 Conclusions

- Post retort residual gas is affected by the retort process. The effects were seen between the two static modes and between static and dynamic process. No significant effects were seen between 5 rpm and 15 rpm.
- Location of the tray within the retort crate was not significant, indicating good heating uniformity throughout the crate and no serious cold spots in any of the four programs.
- The calculated cook time based on the heating factors is significantly impacted by the vacuum condition/residual gas inside the tray and by the retort position or speed
- The slowest Cook Time was observed when the product was packed off under 10 inches of vacuum and processed in a vertical position
- The fastest Cook Time was observed when the product was packed off under 10 inches of vacuum and processed in a rotational retort process at 15 rpm.
- Outliers that were removed from the data would have no effect on the above conclusions if they would not have been removed.

8 References

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5. STATGRAPHICS Plus (2000), A Manugistics Product, Version 5, Manugistics, Inc., Maryland, USA.
6. Heat Penetration Studies of Pork Sausage in Brine in Polymeric Tray, Technical Working Paper #213. Center for Advanced Food Technology, Rutgers, The State University of New Jersey.

9 Attachments

Appendix I: Retort Programs

Appendix II: Data Analysis Static Retort Mode

Appendix III: Data Analysis Rotational Retort Mode

Appendix I

Retort Programs

ICON 2000 Stock America
Retort Program Print

Program # 020 STP1022_DOWN Product # 000000000020 Cont. Size:Poly Tray
Program last changed: 12:03:47 PM 10/16/2000

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

#20

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	0	0	0	0	0
Position:	A	C	C	C	C	C	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 021 STP1022_SIDE Product # 000000000021 Cont. Size:Poly Tray
Program last changed: 12:06:30 PM 10/16/2000

#21

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	0	0	0	0	0
Position:	A	B	B	B	B	B	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 022 STP1022_5RPM Product # 000000000022 Cont. Size:Poly Tray
Program last changed: 12:09:29 PM 10/16/2000

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

#22

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	5	5	5	5	0
Position:	A	A	A	A	A	A	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 023 STP1022_15RP Product # 000000000023 Cont. Size:Poly Tray
Program last changed: 12:11:35 PM 10/16/2000

Program Specific Alarm Tolerances:

#23

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	15	15	15	15	0
Position:	A	A	A	A	A	A	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

Appendix II

Data Analysis Static Retort Mode

Refined Data

Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	Cook Time
R010131A	20	10	1	7	290	0.9	77.21	89.41
R010131A	20	10	4	4	350	0.89	76.99	88.83
R010131A	20	10	5	7	320	0.98	67.62	82.97
R010131A	20	10	7	9	335	0.98	69.23	84.54
R010131A	20	10	8	8	320	0.96	69.39	84.08
R010131A	20	10	9	5	340	0.95	73.11	87.32
R010131A	20	10	10	8	300	1.07	72.08	90.07
R010131A	20	10	13	4	325	1.03	67.65	84.46
R010131A	20	10	15	6	340	0.9	73.39	85.87
R010131A	20	10	16	9	360	1.03	74.56	91.32
R010201B	20	20	1	8	124	1.15	56.27	75.61
R010201B	20	20	3	8	104	1.09	56	74.02
R010201B	20	20	4	6	100	1.13	55.1	73.94
R010201B	20	20	5	4	106	1.06	57.42	74.82
R010201B	20	20	6	9	128	1.09	58.79	76.95
R010201B	20	20	7	6	102	1.06	58.15	75.57
R010201B	20	20	8	7	106	1.1	55.5	73.71
R010201B	20	20	9	7	94	1.07	57.64	75.28
R010201B	20	20	10	4	150	1.14	57.24	76.44
R010201B	20	20	13	5	88	1.08	55.72	73.5
R010201B	20	20	15	9	108	1.1	58.13	76.49
R010201B	20	20	16	5	114	1.16	56.03	75.57
R010214C	20	10	1	5	270	1.1	64.31	82.95
R010214C	20	10	4	8	290	1.03	70.46	87.26
R010214C	20	10	5	4	320	1.12	69.43	88.76
R010214C	20	10	7	5	290	1.06	69.81	87.49
R010214C	20	10	9	8	300	1.15	67.22	87.25
R010214C	20	10	13	7	325	1.08	64.66	82.79
R010214C	20	10	15	6	315	1.05	66.28	83.64
R010214C	20	10	16	6	315	1.01	73.79	89.94
R010215A	20	20	1	6	120	1.07	60.97	78.73
R010215A	20	20	3	7	126	1.08	61.4	79.43
R010215A	20	20	4	5	102	1.08	60.19	78.17
R010215A	20	20	5	5	110	1.11	55.04	73.44
R010215A	20	20	6	9	122	1.04	61.99	79.02
R010215A	20	20	7	9	124	1.11	56.93	75.45
R010215A	20	20	8	4	98	1.15	54.66	73.88
R010215A	20	20	9	8	118	1.05	61.42	78.7
R010215A	20	20	10	4	104	1.05	56.49	73.62
R010215A	20	20	13	8	94	1.15	54.89	74.13
R010215A	20	20	15	6	120	1.14	57.5	76.72
R010215A	20	20	16	7	102	1.09	57.69	75.8
R010125A	21	20	1	9	158	1.07	55.47	73.02
R010125A	21	20	3	9	138	1.07	54.19	71.67
R010125A	21	20	4	8	128	0.91	58.53	72.09
R010125A	21	20	5	6	168	1.03	61.16	77.92
R010125A	21	20	6	8	182	1.04	56.85	73.76
R010125A	21	20	7	5	132	1.03	57.59	72.28
R010125A	21	20	8	6	144	1.07	57	74.61
R010125A	21	20	9	5	158	1.04	59.58	76.56

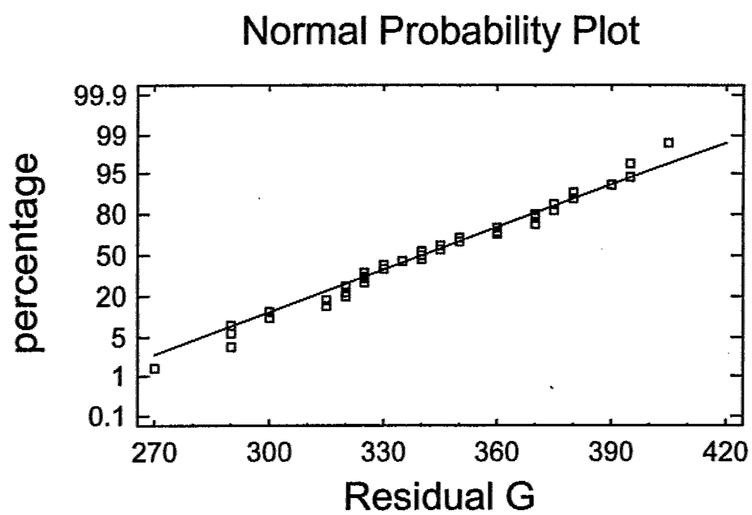
Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	Cook Time
R010125A	21	20	10	4	142	0.98	60.07	75.51
R010125A	21	20	13	7	126	1.09	55.9	73.92
R010125A	21	20	15	7	146	1.01	58.39	74.6
R010125A	21	20	16	4	132	1.04	58.64	75.6
R010126A	21	10	4	4	370	0.98	76.48	91.56
R010126A	21	10	5	8	405	0.99	72.6	88.14
R010126A	21	10	6	9	375	0.98	72.35	87.58
R010126A	21	10	7	7	370	1	74.44	90.25
R010126A	21	10	8	4	380	0.98	74.22	89.38
R010126A	21	10	9	5	395	0.96	75.43	89.88
R010126A	21	10	10	6	390	1.01	75.09	91.21
R010126A	21	10	13	7	395	0.95	75.26	89.37
R010126A	21	10	15	6	375	0.92	75.22	88.28
R010126A	21	10	16	5	370	0.97	76.48	91.22
R010201C	21	20	1	8	120	1.13	53.36	72.07
R010201C	21	20	3	9	132	1.14	55.06	74.1
R010201C	21	20	4	6	142	1.1	58.11	76.47
R010201C	21	20	5	6	116	1.1	56.52	74.79
R010201C	21	20	6	8	112	1.12	52.94	71.41
R010201C	21	20	7	7	134	1.09	56.68	74.74
R010201C	21	20	8	5	116	1.03	54.78	71.39
R010201C	21	20	9	9	124	1.02	53.85	70.2
R010201C	21	20	13	4	136	1.11	55.71	74.16
R010201C	21	20	15	7	124	1.02	55.18	71.56
R010201C	21	20	16	4	124	1.03	55.25	71.87
R010214B	21	10	3	6	330	1.1	72.2	91.06
R010214B	21	10	4	5	340	1.11	69.61	88.68
R010214B	21	10	5	4	360	1.1	73.9	92.78
R010214B	21	10	6	5	325	1.03	70.36	87.17
R010214B	21	10	7	8	350	1.09	69.64	88.16
R010214B	21	10	8	7	345	1.13	68.96	88.47
R010214B	21	10	9	6	380	1.11	71.53	90.65
R010214B	21	10	10	4	330	1.05	71.34	88.73
R010214B	21	10	13	9	345	1.11	68.66	87.7
R010214B	21	10	15	9	325	1.09	68.32	86.81
R010214B	21	10	16	8	360	1.1	70.46	89.28

1. RESIDUAL GAS ANALYSIS

a.1 Probability Plot - Residual G (Vacuum=10 & first(86))

Analysis Summary

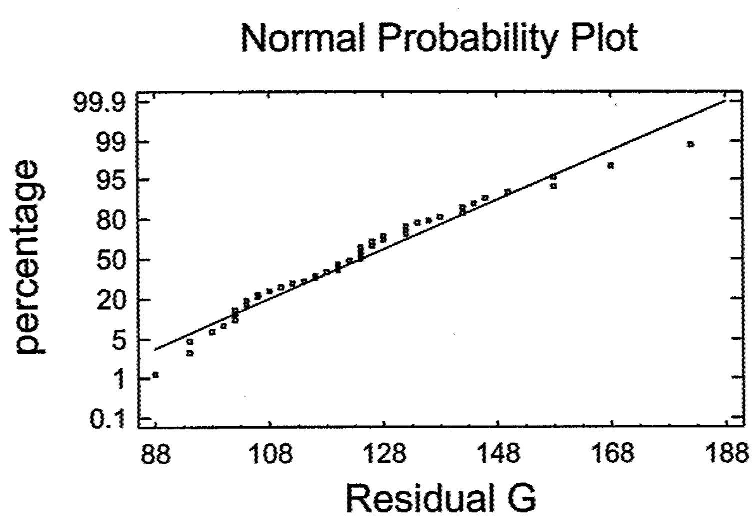
```
Data variable: Residual G
39 values ranging from 270.0 to 405.0
```



a.2 Probability Plot - Residual G (Vacuum=20 & first(86))

Analysis Summary

```
Data variable: Residual G
47 values ranging from 88.0 to 182.0
```



b. Multifactor ANOVA - Residual G (first (86))

Analysis Summary
Dependent variable: Residual G
Factors:
  Program
  Vacuum
Selection variable: first (86)
Number of complete cases: 86

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1.04228E6	3	347427.0	874.53	0.0000
Residual	32576.3	82	397.272		
Total (Corr.)	1.07486E6	85			

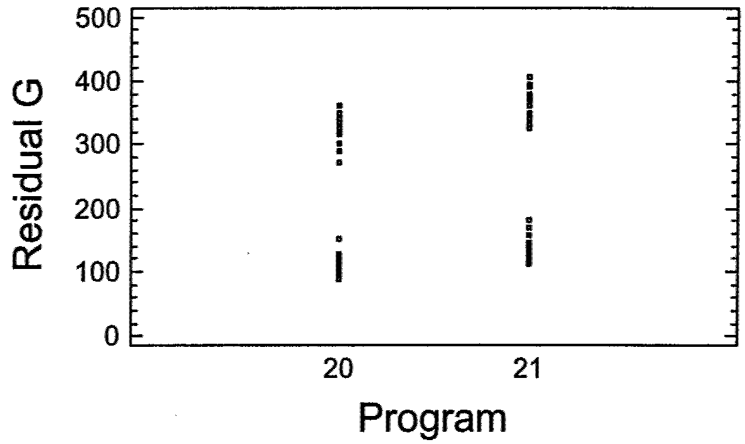
```
R-squared = 96.9692 percent
R-squared (adjusted for d.f.) = 96.8584 percent
Standard Error of Est. = 19.9317
Mean absolute error = 15.5674
Durbin-Watson statistic = 1.48637 (P=0.0031)
Lag 1 residual autocorrelation = 0.245568
```

Analysis of Variance for Residual G - Type III Sums of Squares

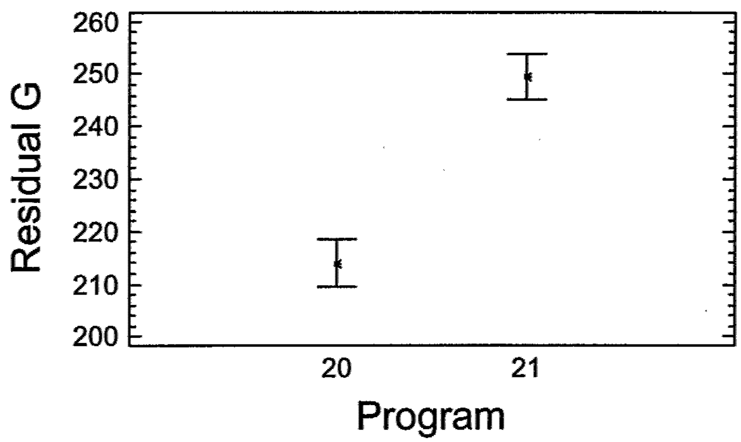
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	26719.7	1	26719.7	67.26	0.0000
B:Vacuum	992385.0	1	992385.0	2498.00	0.0000
INTERACTIONS					
AB	2212.84	1	2212.84	5.57	0.0206
RESIDUAL	32576.3	82	397.272		
TOTAL (CORRECTED)	1.07486E6	85			

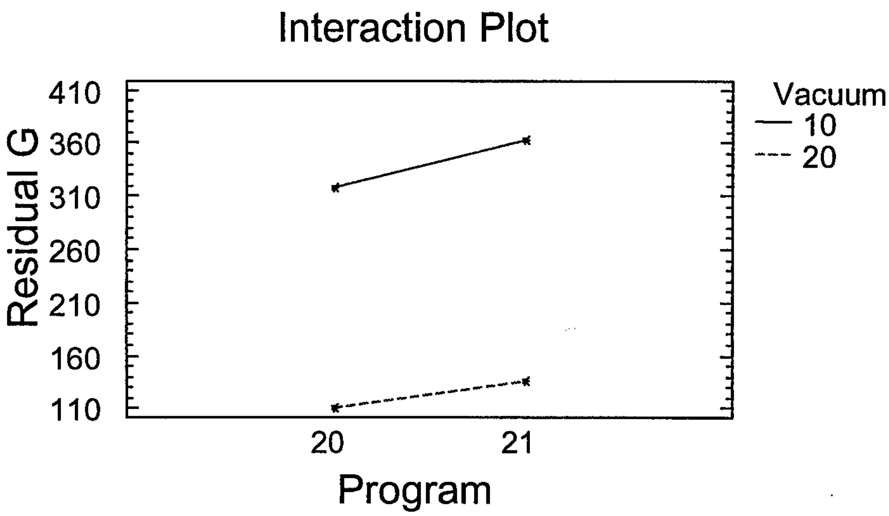
All F-ratios are based on the residual mean square error.

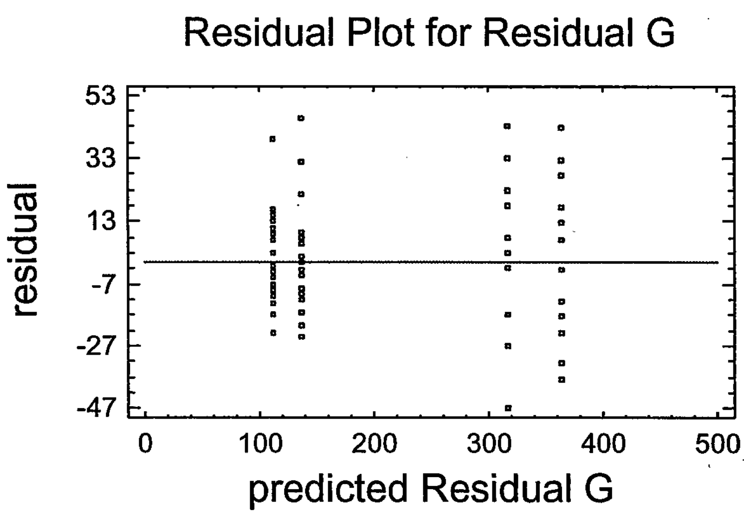
Scatterplot by Level Code



Means and 95.0 Percent Tukey HSD Intervals



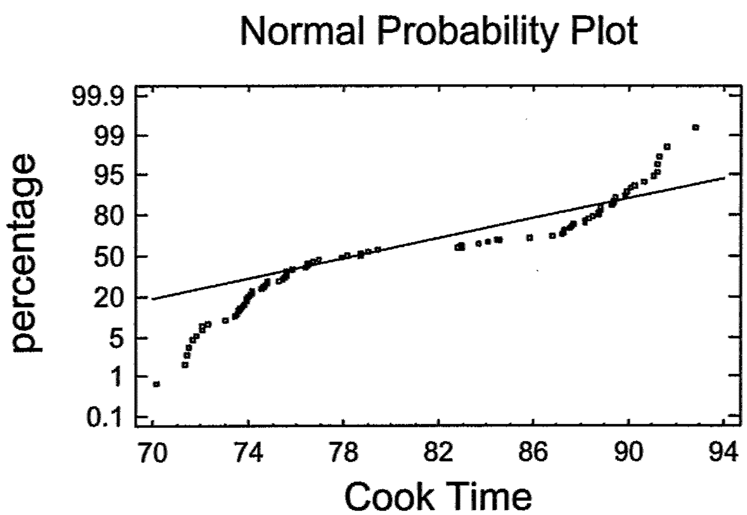

Interaction Plot
Vacuum
10
20
Residual G
410
360
310
260
210
160
110
20
21
Program


Residual Plot for Residual G
residual
53
33
13
-7
-27
-47
0
100
200
300
400
500
predicted Residual G

2. COOK TIME ANALYSIS

a. Probability Plot - CT (first (86))

Analysis Summary
```
Data variable: Cook Time
Selection variable: first (86)
86 values ranging from 70.2 to 92.78
```



b. Multifactor ANOVA - CT (first (86))

Analysis Summary
Dependent variable: CT
Factors:
- Program
- Vacuum

Selection variable: first (86)
Number of complete cases: 86

Analysis of Variance

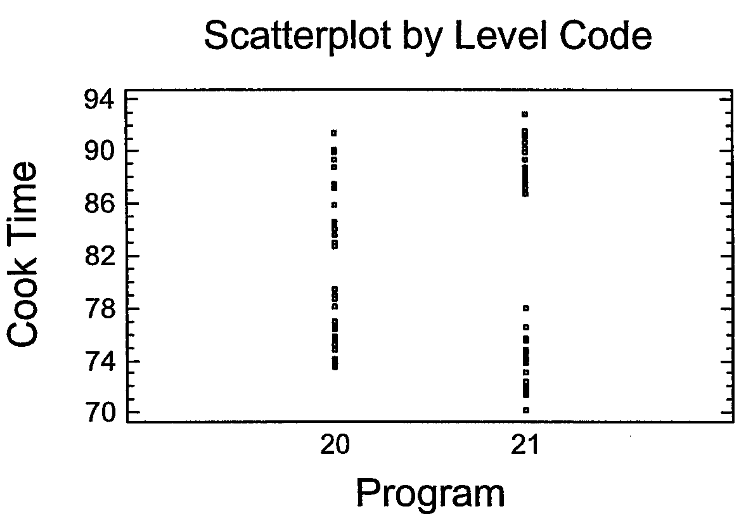
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	3915.5	3	1305.17	302.40	0.0000
Residual	353.916	82	4.31605		
Total (Corr.)	4269.42	85			

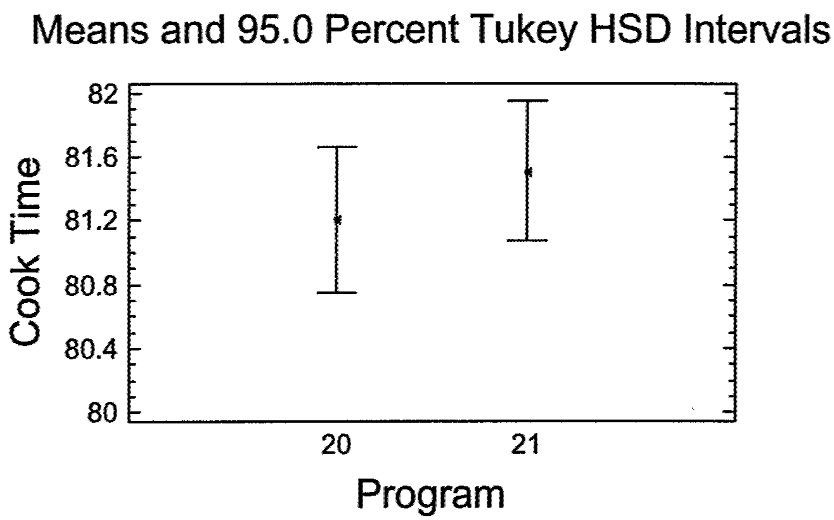
```
R-squared = 91.7104 percent
R-squared (adjusted for d.f.) = 91.4072 percent
Standard Error of Est. = 2.07751
Mean absolute error = 1.69887
Durbin-Watson statistic = 1.89814 (P=0.2174)
Lag 1 residual autocorrelation = 0.0398343
```

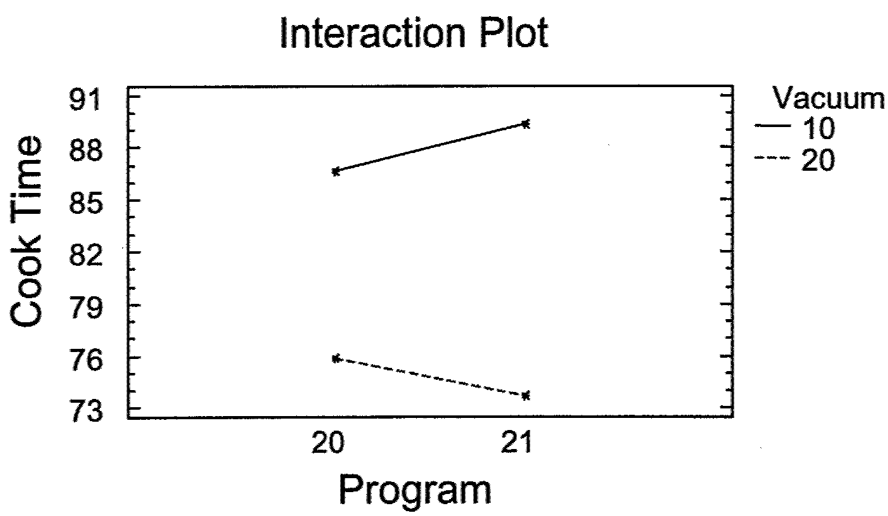
Analysis of Variance for CT - Type III Sums of Squares

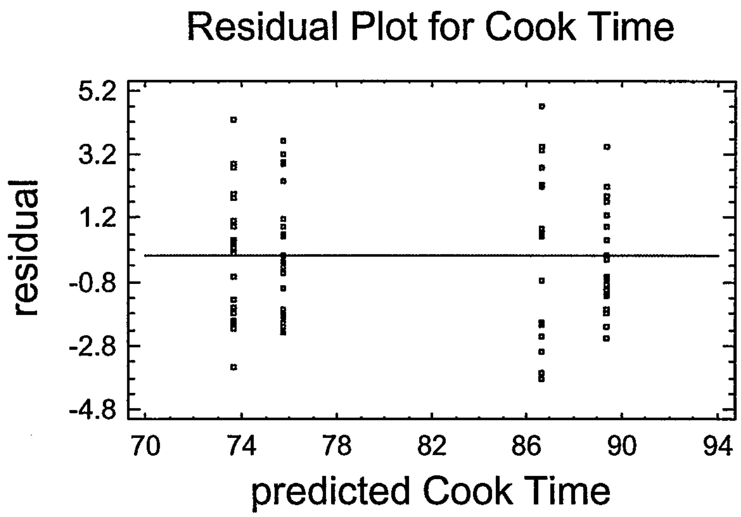
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	2.01568	1	2.01568	0.47	0.4963
B:Vacuum	3729.69	1	3729.69	864.15	0.0000
INTERACTIONS					
AB	125.845	1	125.845	29.16	0.0000
RESIDUAL	353.916	82	4.31605		
TOTAL (CORRECTED)	4269.42	85			

All F-ratios are based on the residual mean square error.




Means and 95.0 Percent Tukey HSD Intervals
Cook Time
82
81.6
81.2
80.8
80.4
80
20
21
Program


Interaction Plot
Cook Time
91
88
85
82
79
76
73
20
21
Program
Vacuum
10
20


Residual Plot for Cook Time
residual
predicted Cook Time
5.2
3.2
1.2
-0.8
-2.8
-4.8
70
74
78
82
86
90
94

3. Location of Tray Analysis:

Program 20

Multiple Range Tests for CT by Location

Method: 95.0 percent LSD

Location	Count	Mean	Homogeneous Groups
5	7	79.7771	X
7	7	79.9129	X
4	7	80.1157	X
9	6	80.6283	X
6	7	80.63	X
8	8	81.39	X

Contrast	Difference	+/- Limits
4 - 5	0.338571	6.77127
4 - 6	-0.514286	6.77127
4 - 7	0.202857	6.77127
4 - 8	-1.27429	6.55626
4 - 9	-0.512619	7.04776
5 - 6	-0.852857	6.77127
5 - 7	-0.135714	6.77127
5 - 8	-1.61286	6.55626
5 - 9	-0.85119	7.04776
6 - 7	0.717143	6.77127
6 - 8	-0.76	6.55626
6 - 9	0.00166667	7.04776
7 - 8	-1.47714	6.55626
7 - 9	-0.715476	7.04776
8 - 9	0.761667	6.84144

* denotes a statistically significant difference.

Program 21

Multiple Range Tests for CT by Location

Method: 95.0 percent LSD

Location	Count	Mean	Homogeneous Groups
9	7	78.7257	X
8	7	79.2729	X
7	7	80.4157	X
4	8	82.4487	X
5	7	82.4543	X
6	8	83.1238	X

Contrast	Difference	+/- Limits
4 - 5	-0.00553571	8.85448
4 - 6	-0.675	8.55424
4 - 7	2.03304	8.85448
4 - 8	3.17589	8.85448
4 - 9	3.72304	8.85448
5 - 6	-0.669464	8.85448
5 - 7	2.03857	9.14487
5 - 8	3.18143	9.14487
5 - 9	3.72857	9.14487
6 - 7	2.70804	8.85448
6 - 8	3.85089	8.85448
6 - 9	4.39804	8.85448
7 - 8	1.14286	9.14487
7 - 9	1.69	9.14487
8 - 9	0.547143	9.14487

* denotes a statistically significant difference.

Appendix III

Data Analysis Rotational Retort Mode

Refined Data

Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	XBH	F2	CT
R010126B	23	10	1	7	265	1.58	29.41	28.13	13.07	42.45
R010126B	23	10	3	6	280	1.43	26.51	37.11	17.49	44.27
R010126B	23	10	4	4	275	1	34.86	36	14.8	46.61
R010126B	23	10	5	5	265	1.87	26.65	38.84	18.07	47.28
R010126B	23	10	6	8	285	1.46	28.88	33.35	14.93	44.89
R010126B	23	10	7	7	270	1.07	37.21	38.56	15.09	49.66
R010126B	23	10	8	4	265	1.33	33.35	22.71	16.78	42.26
R010126B	23	10	9	8	270	1.8	27.8	36.86	14.25	46.9
R010126B	23	10	10	5	290	1.55	27.46	34.3	13.8	44.45
R010126B	23	10	15	9	305	1.67	28.05	31.93	15.42	44.89
R010126B	23	10	16	6	275	1.41	29.31	33.34	13.9	44.62
R010131C	23	10	1	9	260	1.13	46.78	17.79	17.74	42.07
R010131C	23	10	3	4	275	1.34	27.7	20.26	16.45	38.82
R010131C	23	10	4	5	275	1.43	27.86	26.88	15	41.38
R010131C	23	10	5	7	255	1.17	36.94	16.88	21.67	43.23
R010131C	23	10	6	6	305	1.3	29	28.01	15.65	42.1
R010131C	23	10	7	8	290	1.09	55.37	19.73	20.15	46.28
R010131C	23	10	8	4	270	1.32	32.23	32.81	14.61	45.74
R010131C	23	10	9	9	250	1.15	34.38	28.76	14.41	43.48
R010131C	23	10	10	5	260	1.24	36.82	27.84	16.68	45.55
R010131C	23	10	13	7	300	1.28	30.32	20.8	15.89	39.41
R010131C	23	10	15	6	250	1.31	30.19	29.7	17.14	44.09
R010131C	23	10	16	8	255	1.09	42.36	17.5	16.43	39.8
R010201A	23	20	1	7	106	1.17	45.94	34.08	24.64	55.69
R010201A	23	20	3	6	112	1.16	41.62	37.36	19.99	53.34
R010201A	23	20	5	4	92	1.1	46.59	29.12	25.62	53.52
R010201A	23	20	6	8	118	1.13	44.95	26.16	24.61	51.34
R010201A	23	20	7	9	98	1.12	54.26	19.66	32.39	56.5
R010201A	23	20	8	8	132	1.16	42.5	29.83	20.7	50.25
R010201A	23	20	9	7	110	1.13	45.34	20.87	26.39	50.67
R010201A	23	20	10	6	102	1.1	48.71	26.16	26.27	53.25
R010201A	23	20	13	4	120	1.16	42.7	16.81	28.55	50.11
R010201A	23	20	15	5	114	1.12	49.2	16.77	27.02	49.86
R010201A	23	20	16	9	108	1.14	46.66	37.92	20.9	55.91
R010215C	23	20	1	8-4	140	1.09	57.94	25.05	22.04	51.56
R010215C	23	20	3	4-4	98	1.11	45.55	22.18	28.06	51.94
R010215C	23	20	4	7-1	88	1.1	43.04	19.12	31.31	52.3
R010215C	23	20	5	9-1	84	1.15	44.67	19.77	32.82	54.7
R010215C	23	20	6	6-2	90	1.13	46.2	24.01	28.95	53.65
R010215C	23	20	7	8-2	96	1.12	45.56	17.5	30.64	52.28
R010215C	23	20	8	5-3	88	1.1	55.03	22.45	30.29	56
R010215C	23	20	10	7-3	104	1.1	49.21	16.04	28.61	50.66
R010215C	23	20	13	5-1	88	1.16	43.64	23.75	31.43	54.59
R010215C	23	20	15	9-3	98	1.1	48.97	25.31	29.37	54.97
R010215C	23	20	16	4-2	100	1.15	45.3	26.77	23.32	51.11
R010124B	23	20	3	6	104	1.15	48.93	43.34	17.95	58.68
R010124B	23	20	4	7	100	1.14	51.98	22.81	26.12	52.77
R010124B	23	20	5	8	82	1.12	49.51	33.21	28.24	58
R010124B	23	20	8	4	102	1.11	52.24	24.61	23.83	51.76

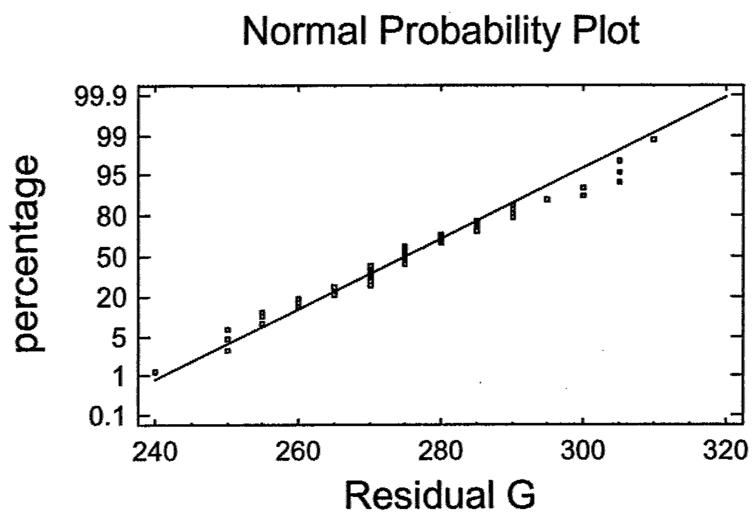
Run	Program	Vacuum	TC	Location	Res. Gas	JH	FH	XBH	F2	CT
R010124B	23	20	9	7	90	1.12	50.37	25.9	26.45	53.92
R010124B	23	20	10	5	86	1.15	46.57	26.78	22.04	50.65
R010124B	23	20	13	8	92	1.12	50.49	42.06	19.78	58.97
R010124B	23	20	15	5	122	1.11	47.38	32.62	15.65	50.05
R010124B	23	20	1	9	104	1.16	46.52	29.13	22.51	52.24
R010131B	22	10	1	4	295	1.2	41.31	25.94	29.03	53.25
R010131B	22	10	3	7	300	1.23	41.39	23.74	32.11	54.89
R010131B	22	10	4	6	270	1.19	40.65	21.62	25.08	48.92
R010131B	22	10	5	4	270	1.29	38.77	20.75	27.02	50.24
R010131B	22	10	6	8	285	1.17	39.31	20.91	28.05	52.88
R010131B	22	10	7	8	275	1.26	40.21	26.48	29.69	53.89
R010131B	22	10	8	5	280	1.21	42.57	28.78	29.24	54.9
R010131B	22	10	10	7	305	1.18	39.71	21.36	23.91	47.61
R010131B	22	10	13	9	310	1.26	37.74	26.66	31.06	53.34
R010131B	22	10	15	6	285	1.19	43.84	12.36	33.76	53.89
R010131B	22	10	16	9	270	1.19	50.31	26.66	23.82	53.13
R010214A	22	10	1	9	290	1.09	50.86	16.84	25.05	48.2
R010214A	22	10	3	7	290	1.09	60.5	15.53	26.25	49.86
R010214A	22	10	4	8	280	1.09	58.89	15.97	28.46	51.92
R010214A	22	10	5	4	255	1.11	56.3	10	32.35	52.66
R010214A	22	10	6	8	240	1.08	49.22	29.48	26.41	54.81
R010214A	22	10	7	9	260	1.15	49.02	23.62	23.47	50.62
R010214A	22	10	8	6	285	1.12	43.97	25.62	20.64	48.17
R010214A	22	10	9	7	270	1.16	41.64	18.32	23.15	46.14
R010214A	22	10	10	4	280	1.12	45.57	26.4	26.23	52.56
R010214A	22	10	13	5	275	1.12	55.55	15.23	26.12	49.29
R010214A	22	10	15	6	250	1.14	45.27	19.85	28.69	51.76
R010214A	22	10	16	5	275	1.16	42.05	20.91	28.85	51.46
R010125B	22	20	1	9	108	1.15	51.7	36.79	37.36	64.88
R010125B	22	20	3	7	94	1.18	47.49	37.13	39.03	63.62
R010125B	22	20	4	8	110	1.14	45.54	38.59	34.96	60.71
R010125B	22	20	5	4	88	1.15	49.13	40.47	41.92	65.76
R010125B	22	20	6	8	124	1.16	51.99	36.78	35.68	64.42
R010125B	22	20	7	6	94	1.14	50.36	48.42	46.4	68.4
R010125B	22	20	8	6	116	1.19	49.49	45.03	34.43	65.41
R010125B	22	20	9	4	96	1.15	50.5	47.62	35.34	66.46
R010125B	22	20	10	7	84	1.14	51.78	47.79	24.13	64.27
R010125B	22	20	13	9	90	1.16	50.83	50.19	32.84	67.04
R010125B	22	20	15	5	104	1.11	50.85	49.21	39.92	67.35
R010215B	22	20	1	8-1	88	1.11	49.16	30.31	37.82	61.62
R010215B	22	20	3	4-1	100	1.18	47.64	21.59	36.56	59.2
R010215B	22	20	4	8-3	88	1.14	47.55	20.29	35.96	57.9
R010215B	22	20	5	7-4	102	1.1	52.78	37.56	28.34	61
R010215B	22	20	6	7-2	90	1.08	52.31	17.92	41.15	61.69
R010215B	22	20	7	9-4	98	1.09	53.9	16.59	44.52	64.61
R010215B	22	20	8	6-3	88	1.1	53.22	28.49	46.61	67.72
R010215B	22	20	9	5-1	90	1.11	54.64	19.61	43.81	65.18
R010215B	22	20	13	6-1	78	1.09	47.44	30.69	39.47	61.32
R010215B	22	20	15	9-2	104	1.08	53.11	19.78	38.84	60.63
R010215B	22	20	16	4-3	100	1.09	56.75	33.75	27.49	59.93

1. RESIDUAL GAS ANALYSIS

a.1 Probability Plot - Residual G (Vacuum=10 & last(99))

Analysis Summary

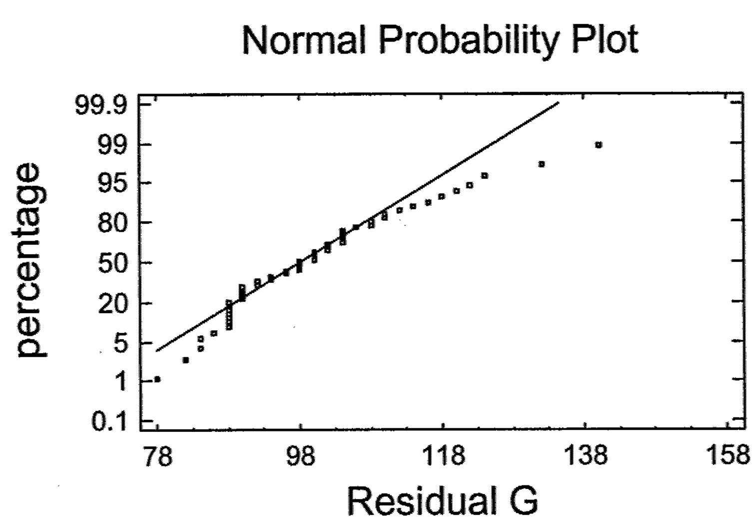
```
Data variable: Residual G
46 values ranging from 240.0 to 310.0
```



a.2 Probability Plot - Residual G (Vacuum=20 & last(99))

Analysis Summary

```
Data variable: Residual G
53 values ranging from 78.0 to 140.0
```



b. Multifactor ANOVA - Residual G (last (99))

Analysis Summary

```
Dependent variable: Residual G
Factors:
        Program
        Vacuum
Selection variable: last (99)
Number of complete cases: 99
```

Analysis of Variance

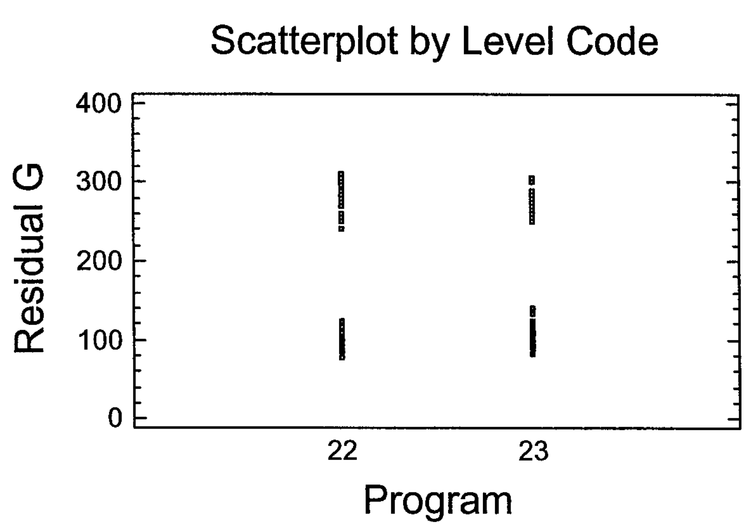
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	761012.0	3	253671.0	1173.06	0.0000
Residual	20543.5	95	216.248		
Total (Corr.)	781555.0	98			

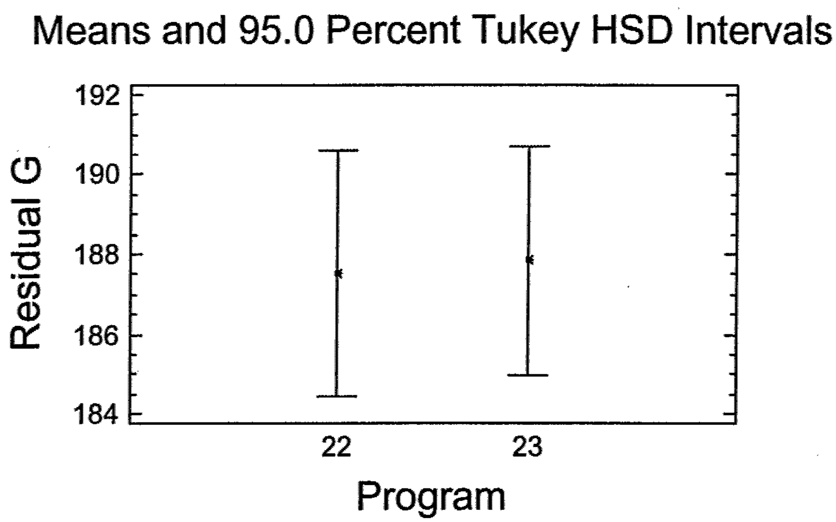
```
R-squared = 97.3715 percent
R-squared (adjusted for d.f.) = 97.2884 percent
Standard Error of Est. = 14.7054
Mean absolute error = 11.2465
Durbin-Watson statistic = 1.67745 (P=0.0275)
Lag 1 residual autocorrelation = 0.158215
```

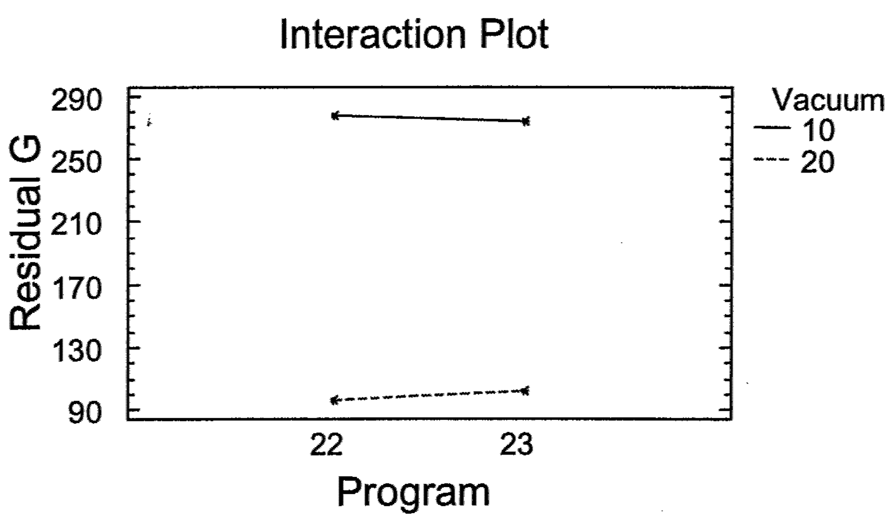
Analysis of Variance for Residual G - Type III Sums of Squares

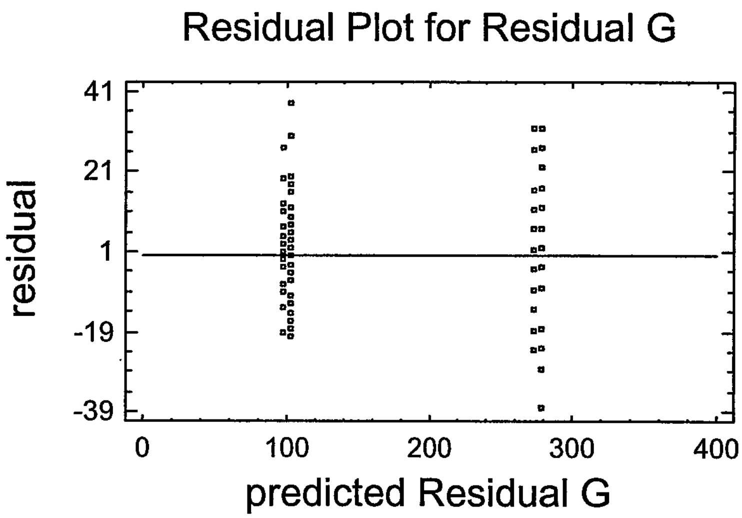
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	2.39753	1	2.39753	0.01	0.9164
B:Vacuum	753846.0	1	753846.0	3486.03	0.0000
INTERACTIONS					
AB	578.332	1	578.332	2.67	0.1053
RESIDUAL	20543.5	95	216.248		
TOTAL (CORRECTED)	781555.0	98			

All F-ratios are based on the residual mean square error.




Means and 95.0 Percent Tukey HSD Intervals
192
190
188
186
184
Residual G
22
23
Program

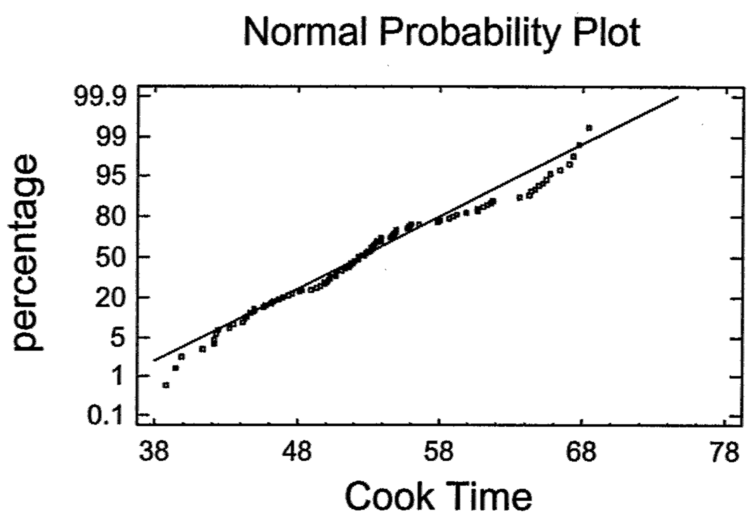

Interaction Plot
290
250
210
170
130
90
Residual G
22
23
Program
Vacuum
10
20


Residual Plot for Residual G
residual
41
21
1
-19
-39
0
100
200
300
400
predicted Residual G

2. COOK TIME ANALYSIS

a. Probability Plot - CT (last (99))

Analysis Summary
Data variable: Cook Time
99 values ranging from 38.82 to 68.4



b. Multifactor ANOVA - CT (last (99))

Analysis Summary
Dependent variable: CT
Factors:
Program
Vacuum
Selection variable: last (99)
Number of complete cases: 99

Analysis of Variance

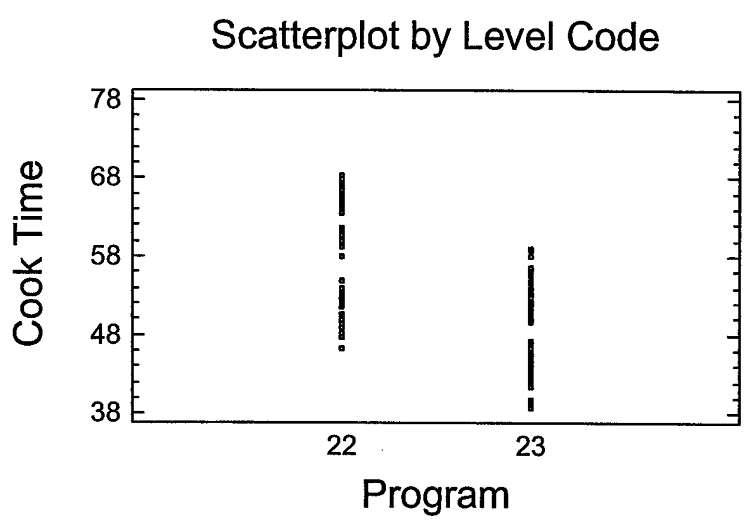
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	4419.45	3	1473.15	202.53	0.0000
Residual	690.998	95	7.27366		
Total (Corr.)	5110.45	98			

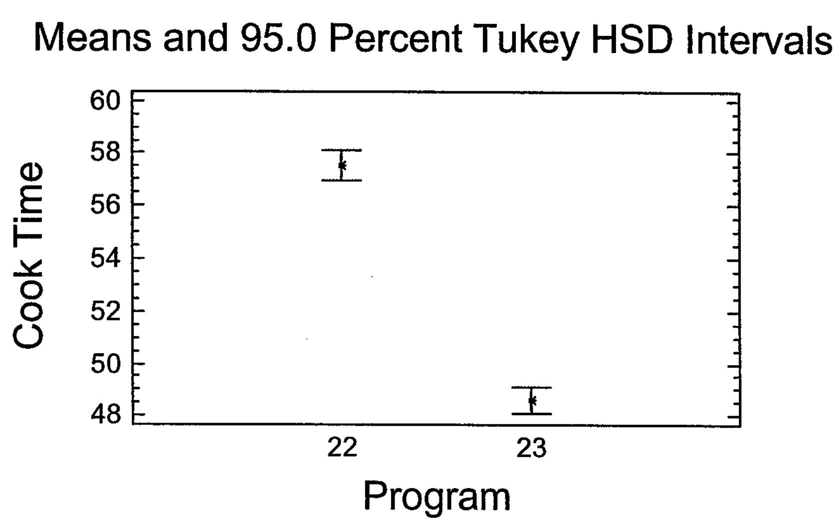
R-squared = 86.4787 percent
R-squared (adjusted for d.f.) = 86.0517 percent
Standard Error of Est. = 2.69697
Mean absolute error = 2.21735
Durbin-Watson statistic = 1.79956 (P=0.0968)
Lag 1 residual autocorrelation = 0.0956626

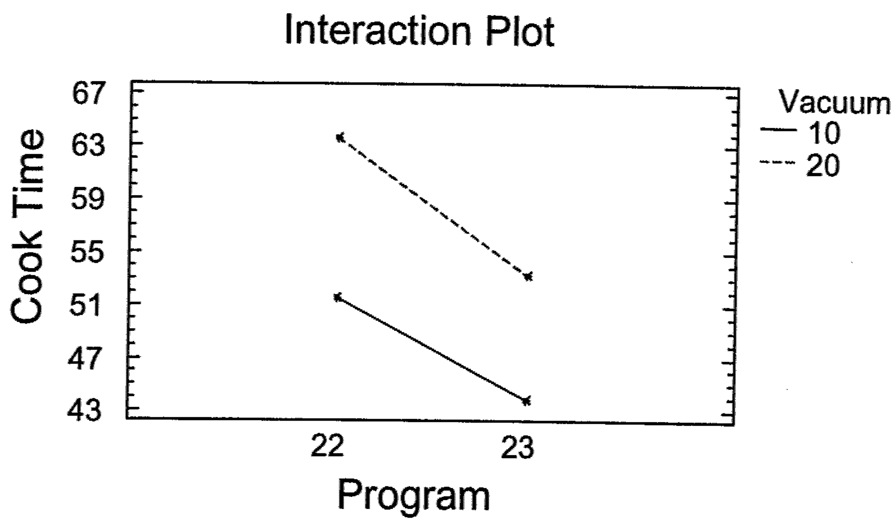
Analysis of Variance for CT - Type III Sums of Squares

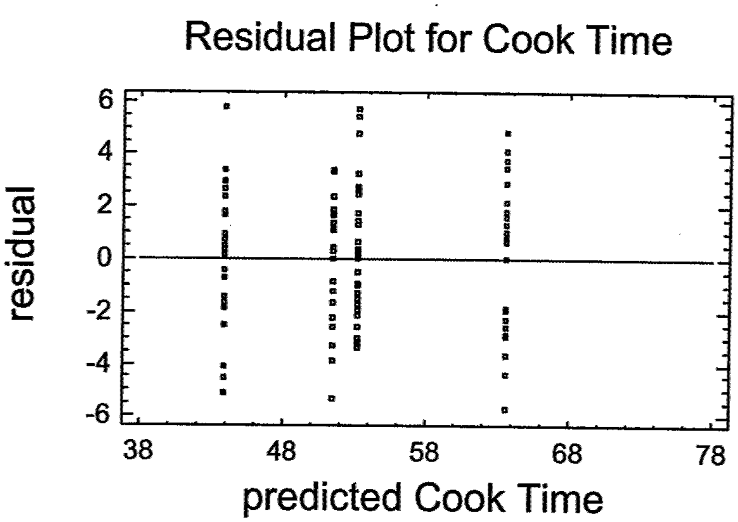
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Program	1946.37	1	1946.37	267.59	0.0000
B:Vacuum	2792.52	1	2792.52	383.92	0.0000
INTERACTIONS					
AB	46.2059	1	46.2059	6.35	0.0134
RESIDUAL	690.998	95	7.27366		
TOTAL (CORRECTED)	5110.45	98			

All F-ratios are based on the residual mean square error.






Interaction Plot
Vacuum
10
20
Cook Time
67
63
59
55
51
47
43
22
23
Program


Residual Plot for Cook Time
residual
6
4
2
0
-2
-4
-6
38
48
58
68
78
predicted Cook Time

3. Location of Tray Analysis

Program 22

Multiple Range Tests for CT by Location

Method: 95.0 percent LSD

Location	Count	Mean	Homogeneous Groups
7	8	56.135	X
8	8	57.2688	X
4	8	57.5075	X
5	5	57.636	X
9	8	57.8062	X
6	8	58.1987	X

Contrast	Difference	+/- Limits
4 - 5	-0.1285	8.17212
4 - 6	-0.69125	7.16742
4 - 7	1.3725	7.16742
4 - 8	0.23875	7.16742
4 - 9	-0.29875	7.16742
5 - 6	-0.56275	8.17212
5 - 7	1.501	8.17212
5 - 8	0.36725	8.17212
5 - 9	-0.17025	8.17212
6 - 7	2.06375	7.16742
6 - 8	0.93	7.16742
6 - 9	0.3925	7.16742
7 - 8	-1.13375	7.16742
7 - 9	-1.67125	7.16742
8 - 9	-0.5375	7.16742

* denotes a statistically significant difference.

Program 23

Multiple Range Tests for CT by Location

Method: 95.0 percent LSD

Location	Count	Mean	Homogeneous Groups
4	9	47.9856	X
5	9	48.8678	X
7	10	49.076	X
6	8	49.25	X
8	10	50.027	X
9	8	50.595	X

Contrast	Difference	+/- Limits
4 - 5	-0.882222	5.25443
4 - 6	-1.26444	5.41614
4 - 7	-1.09044	5.12139
4 - 8	-2.04144	5.12139
4 - 9	-2.60944	5.41614
5 - 6	-0.382222	5.41614
5 - 7	-0.208222	5.12139
5 - 8	-1.15922	5.12139
5 - 9	-1.72722	5.41614
6 - 7	0.174	5.28717
6 - 8	-0.777	5.28717
6 - 9	-1.345	5.57316
7 - 8	-0.951	4.98479
7 - 9	-1.519	5.28717
8 - 9	-0.568	5.28717

* denotes a statistically significant difference.

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Economic Modeling and Analysis

of the

Manufacturing Cost Polymeric Tray

Technical Working Paper (TWP) 215

Rieks Bruins

August, 2000

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Introduction

Earlier manufacturing studies examined polymeric tray pack production at fixed production rates which were based on semi-commercial rates ranging from 2 to 10 trays/min. The commercial heat sealer at Rutgers routinely processes non-military polymeric trays at 15 trays/min and the heat sealer is rated at 30 trays/min. It is expected that operating rates have a significant impact on production economics but might be limited by specification constraints.

The retort capacity decreases significantly when the industry switches over to the polymeric half steam table tray due to its slightly larger size and the fact that the weight of each container needs to be supported by a racking mechanism rather stacking the containers on top of each other. A typical Stock 1100 retorts can only process 192 polymeric containers per load versus 288 metal containers. However, if a properly designed rack is used, one might be able to rotate the product during the retort process. The heating rate of some products can be significantly affected by this rotation and be able to at least partially off set the loss in batch size by decreasing the cycle time.

Objective

Perform a production system-analysis including subsystems for filling, sealing and retorting of product in polymeric trays. The analysis output is to include impact of production rates and investments on cost per unit.

Modeling

A system analysis of a production system requires modeling tools that relate the various unit operations. Higher filling speeds for example impact down stream operations and the overall cost of the product. This project utilized an existing economic production model developed under a CRAMTD project. The model is based on an Excel spreadsheet that models the production system for the Polymeric Tray manufacturing and calculates the manufacturing cost per unit basis based on various production assumptions such as production schedule, rate and yield. It is a steady state model rather than a dynamic model which takes into account startup issues. At this particular phase, a steady state model is more appropriate as we are not trying to fine tune an existing operation, but rather trying to identify overall relationships between various unit operations and the effects on production cost

Assumptions

The results of any kind of modeling effort are greatly affected by the assumptions made regarding the production requirements, the production yields and efficiencies, and the methods used to calculate the cost. The results of the analysis are therefore more of a relative nature rather than of an absolute nature.

Production Scenario's

Two basic scenarios were used for production requirements.
Scenario 1 is based on peace time requirements of 900,000 trays annually. The production is split between three producers with similar production capabilities. It is assumed that the producer will have an 8 hour production shift operation, five days per week and up to 48 weeks/year and that the production rate needs to take place within a 50% plant utilization rate. This means that the product can be produced within a 6 month time frame.

Scenario 2 is based on war time requirements of 8,800,000 trays to be produced in a 215 day period. The production is split between three producers with similar capabilities. It is assumed that the producer will have a three shift operation, six days a week.

Production Cost Calculations

The production cost is a compilation of both fixed cost and variable cost. Fixed costs are items that are independent of the production rate such as equipment depreciation, maintenance and repair, taxes, insurance, etc. Variable costs are items that are directly related to the production rate, such as raw material cost, labor, utilities, etc. In calculating the impact of the fixed cost items on the production cost, assumptions needs to be made if the production line is dedicated to only the polymeric tray ration product or if the production line is used during the "idle" time to produce other products. In the later case the fixed cost component will be shared between both products. In our calculations we looked at both cases. In Cost Case A (unlimited production), we assume that the producer has civilian products that make use of the line when ever it is not being used for military production and the fixed cost will be prorated based on time utilization

In Cost Case B (limited production), we assume hat the producer has a dedicated line for the polymeric tray production and that all fixed cost needs to be paid by the ration.

Product Yield and Process Efficiencies

For each unit operation, assumptions need to be made regarding the efficiencies of process operations: eg what percent of the scheduled production time will equipment not be available for production.

For each step in the process, assumptions need to be made what the yield of the process is: eg how much product is lost during a process operation either due to defective product or due to material losses/shrinkage.

Material Cost

Estimates were made for the product and package material cost associated with the production of Pork Sausage in Brine and Creamed Ground Beef. Vendors were requested to give us pricing information based on production type volumes. In cases where we were not able to obtain a quote, a best guess was made based on historical and comparable information. Somewhat lower pricing can probably be obtained via long term contract negotiations. It was assumed that both the precooked pork sausage and the precooked ground beef would be obtained from outside sources rather than manufacturing these ingredients in house.

Labor Cost

Estimates were made for labor requirements to support the production of the polymeric half steam table tray product. Certain labor requirements are production rate sensitive, such as the inspection process of trays. The labor requirements for these operations were programmed as a function of the production rate and cycle time requirements. The cost of labor was estimated based on local wages. Wages in other parts of the country might differ.

Capital Equipment

Estimates were made for the capital equipment that is needed for the production of a polymeric half steam table tray product. It was anticipated that the retort equipment would be the capacity limiting factor in this production line and was programmed into the model as a function of production rate and retort cycle time. It was assumed that all other capital equipment would be able to support high speed manufacturing. The purchase of capital equipment leads to other cost such as installation, instrumentation, infra structure, etc. Standard factors that can be found in engineering hand books were used to estimate the associated cost with

new capital equipment in order to estimate the total capital investment needs. Building cost or rent were not estimated in this model.

Utility Cost

Utility cost was added to the model as a place holder at this time and no relationships were setup to make utility cost a function of production rate. A total utility cost of approximately $69,000 per year was estimated at this time. Further refinements of the model in this area could consider to increase the functionality of the model.

Manufacturing Cost

Manufacturing cost is the cost that can be associated to the production of the product. The manufacturing cost is built up from two components, the variable cost component and the fixed cost component. The variable cost component includes raw material and packaging material cost as well as labor cost and utility cost. The fixed cost component includes those cost that can be associated with the capital equipment such as depreciation, maintenance, operating supplies, taxes, insurance, financing cost, rent, etc. The percentage numbers used for these calculations are based on numbers used in engineering handbooks and practical experience in the food industry. A 7% overhead cost was added to the subtotal of the fixed and variable cost in order to calculate the total manufacturing cost.

The total manufacturing cost was used to calculate the manufacturing cost per product unit, in this case one tray. Two cost scenario's were used to make these calculation. **Unlimited Production** assumes the producer to produce this product year around at the same rate and be able to sell the excess product to commercial customers (Case A). **Limited Production** assumes that the producer has a dedicated facility in which he will only produce the ration and shut the line down when the contract requirements are met (Case B). In reality, the producer might be able to produce under a mixed case scenario in which certain parts of the process and capital equipment can be used for the production of alternate products.

Base Case

Appendix A contains the cost calculations of a base case, scenario 1 (peace time) in which the production line speed is set at 10 trays a minute both for the pork sausage in brine and for the creamed ground beef. The production schedule is based on one shift per day, five days/week and the output requirements of 300,000 cans per producer. Retort cycle times were estimated for each product using Stock 1100 retorts in a static configuration (192 minutes for Creamed Ground Beef and 105 minutes for Sausage in Brine). The first cost number is based on the unlimited production assumption, the second cost number, higher cost number, is based on the limited production assumption

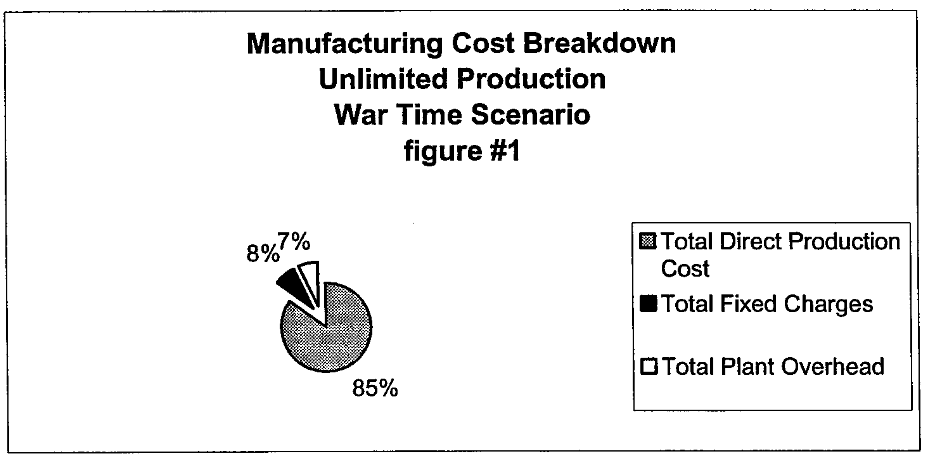
Manufacturing Cost of Creamed Ground Beef: $14.065/21.975, using 12 retorts
Manufacturing Cost of Sausage in Brine: $12.863/18.697, using 7 retorts

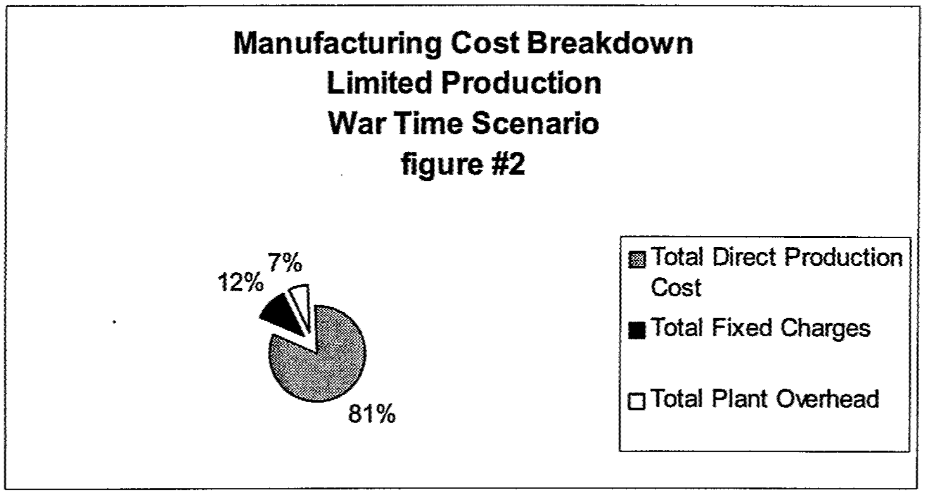
Appendix B contains the cost calculations of the base case, scenario 2 (war time) in which the production line speed is set at 15 trays/min and the same retort cycle times are used. The production schedule is now based on three shifts per day, six days/week and the output requirements have increased to 3,000,000 containers per producer which needs to be produced in over a 31 week time frame

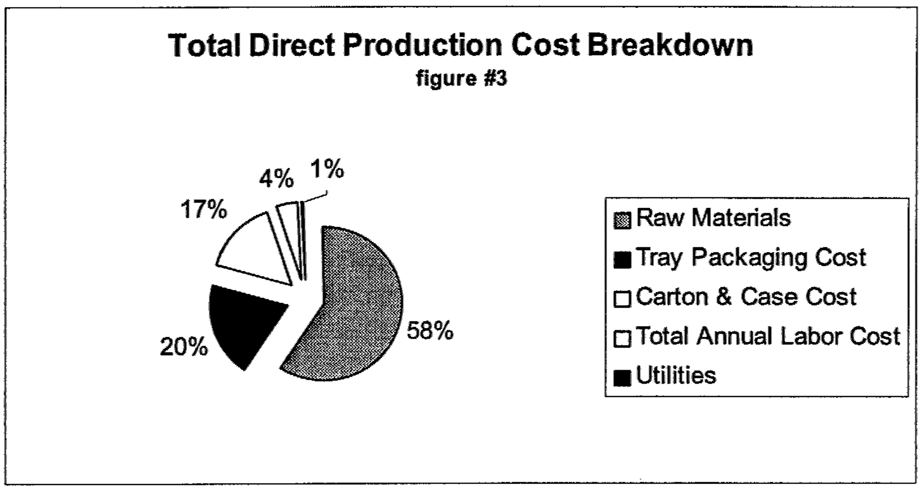
Manufacturing Cost of Creamed Ground Beef: $10.851/11.434, using 17 retorts
Manufacturing Cost of Sausage in Brine: $10.452/10.867, using 10 retorts

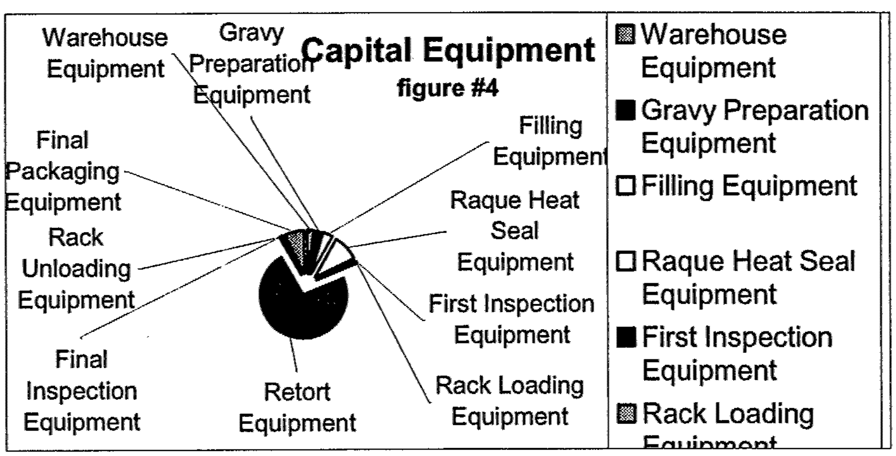
Cost Breakdown

The breakdown the manufacturing cost for the war time scenario, shows that 81-85% of the cost is determined by the "total direct production cost", or variable cost component (see fig 1 and 2). Figure 3 shows a further breakdown of this total direct production cost number and shows that about 37% of this variable cost number is attributed to container and cartoning cost. Figure 4 shows the breakdown of the fixed cost component. The majority of the fixed cost component is associated with the retort equipment.




Manufacturing Cost Breakdown
Limited Production
War Time Scenario
figure #2
7%
12%
81%
Total Direct Production Cost
Total Fixed Charges
Total Plant Overhead


Total Direct Production Cost Breakdown
figure #3
4%
1%
17%
20%
58%
Raw Materials
Tray Packaging Cost
Carton & Case Cost
Total Annual Labor Cost
Utilities


Capital Equipment
figure #4
Warehouse Equipment
Gravy Preparation Equipment
Filling Equipment
Final Packaging Equipment
Raque Heat Seal Equipment
Rack Unloading Equipment
First Inspection Equipment
Final Inspection Equipment
Retort Equipment
Rack Loading Equipment
Warehouse Equipment
Gravy Preparation Equipment
Filling Equipment
Raque Heat Seal Equipment
First Inspection Equipment
Rack Loading

Retort Equipment

Reducing the retort resource requirements has a significant impact on the manufacturing cost calculation. There are several common ways to lessen the retort resource requirement:

a) rotate product during sterilization cycle to forced convective flows,
b) use higher retort temperatures in conjunction with rotation,
c) utilize starches or alternate product formula's that enhance (forced) convective flows within the tray
d) use higher initial product temperatures
e) allow higher residual gas levels in container to assist in forced convective flows during rotational retort cycle

It is anticipated that the retort cycle time can be reduced with as much as 30 to 50% in the majority of products, using the above techniques. This will reduce the required fixed cost component accordingly and regaining the retort capacity that currently can be obtained using the metal half steam table tray. The major concern is however the integrity of the tray and lid stock during these retort cycles. Special retort racks that clamp the tray within a pocket without allowing movement and causing abrasion defects is required. This requirement was considered during the design of the current used retort racks for polymeric trays. Also lid stock which can withstand higher retort temperatures to prevent delamination will be required. The quad laminate seems to be able to full fill this requirement

Comparisons (What If Analysis)

The following tables demonstrate comparisons between production line speed, retort cycle time and post retort inspection yield, using economic model under the war time scenario.

Table #1 compares the number of retorts required as function of the retort cycle time and packaging line speed.

Table #1	Retort Cycle Time			
Packaging Line Speed	80 min	120 min	160 min	200 min
10 trays/minute	5	7	10	12
15 trays/minute	7	11	14	18
20 trays/minute	10	14	19	24
25 trays/minute	12	18	24	29
30 trays/minute	14	21	28	35

Table #2a compares the manufacturing cost of Creamed Ground Beef (limited production cost scenario) as function of the retort cycle time and packaging line speed:

Table #2a	Retort Cycle Time			
Packaging Line Speed	80 min	120 min	160 min	200 min
10 trays/minute	$10.849	$10.977	$11.214	$11.342
15 trays/minute	$10.763	$11.049	$11.242	$11.498
20 trays/minute	$10.929	$11.186	$11.507	$11.850
25 trays/minute	$10.977	$11.362	$11.765	$12.086
30 trays/minute	$11.081	$11.546	$11.995	$12.459

Table #2b compares the manufacturing cost of Creamed Ground Beef (unlimited production cost scenario) as function of the retort cycle time and packaging line speed:

Table #2b	Retort Cycle Time			
Packaging Line Speed	80 min	120 min	160 min	200 min
10 trays/minute	$10.789	$10.907	$11.128	$11.246
15 trays/minute	$10.429	$10.616	$10.733	$10.891
20 trays/minute	$10.360	$10.478	$10.625	$10.794
25 trays/minute	$10.230	$10.371	$10.530	$10.648
30 trays/minute	$10.172	$10.325	$10.462	$10.614

Table #3a compares the manufacturing cost of Creamed Ground Beef (limited production cost scenario) as function of the second inspection yield and the packaging line speed

Table #3a	Post Retort Inspection Yield			
Packaging Line Speed	94%	96%	98%	100%
10 trays/minute	$11.705	$11.520	$11.342	$11.172
15 trays/minute	$11.787	$11.607	$11.434	$11.268
20 trays/minute	$12.137	$11.958	$11.786	$11.621
25 trays/minute	$12.370	$12.192	$12.022	$11.859
30 trays/minute	$12.742	$12.565	$12.395	$12.232

Table #3b compares the manufacturing cost of Creamed Ground Beef (unlimited production cost scenario) as function of the second inspection yield and the packaging line speed

Table #3b	Post Retort Inspection Yield			
Packaging Line Speed	94%	96%	98%	100%
10 trays/minute	$11.654	$11.446	$11.246	$11.053
15 trays/minute	$11.243	$11.043	$10.851	$10.667
20 trays/minute	$11.153	$10.955	$10.765	$10.582
25 trays/minute	$11.007	$10.812	$10.624	$10.445
30 trays/minute	$10.976	$10.781	$10.595	$10.416

Conclusion

The economic model and analysis clearly demonstrates that the retort operation is the most capital intensive part of the process and becomes the bottle neck of the process when number of retorts available is limited. More than likely the available retort capacity in a plant will dictate the packaging line speed. Therefore, the emphasis of this project needs to focus on increasing the capacity retort process. As a second objective we should ensure that line speeds of up to 20 trays per minute are achievable without affecting the process yield.

Appendix A

Manufacturing Cost, Creamed Ground Beef
Peace Time Scenario

		Unlimited Prod	Limited Prod
Direct Production Cost		**Annual Cost**	
Raw Materials		$4,925,070	$1,627,534
Tray Packaging Cost		$1,686,618	$557,358
Carton & Case Cost		$1,386,518	$458,188
Total Annual Labor Cost		$511,680	$169,089
Utilities		$68,868	$22,758
		=========	=========
Total Direct Production Cost		$8,578,755	$2,834,928
Fixed Charges			
Depreciation	10.00% FCI	$1,011,465	$1,011,465
Maintenance and Repair	6.00% FCI	$606,879	$606,879
Operating Supplies	1.00% FCI	$101,147	$101,147
Local Taxes	4.00% FCI	$404,586	$404,586
Insurance	1.00% FCI	$101,147	$101,147
Financing Cost	9.00% TCI	$1,070,963	$1,070,963
Rent		=========	=========
Total Fixed Charges		$3,296,186	$3,296,186
Total Plant Overhead	7.00% TMC	$893,813	$461,482
		=========	=========
Total Manufacturing Cost (TMC)		$12,768,753	$6,592,596
Manufacturing Cost per Packaging Unit		**$14.065**	**$21.975**

Manufacturing Cost, Sausage in Brine
War Time Scenario

		Unlimited Prod	Limited Prod
Direct Production Cost		**Annual Cost**	
Raw Materials		$4,812,166	$1,590,224
Tray Packaging Cost		$1,686,618	$557,358
Carton & Case Cost		$1,386,518	$458,188
Total Annual Labor Cost		$474,240	$156,717
Utilities		$68,868	$22,758
		=========	=========
Total Direct Production Cost		$8,428,410	$2,785,245
Fixed Charges			
Depreciation	10.00% FCI	$746,035	$746,035
Maintenance and Repair	6.00% FCI	$447,621	$447,621
Operating Supplies	1.00% FCI	$74,603	$74,603
Local Taxes	4.00% FCI	$298,414	$298,414
Insurance	1.00% FCI	$74,603	$74,603
Financing Cost	9.00% TCI	$789,919	$789,919
Rent			
		=========	=========
Total Fixed Charges		$2,431,196	$2,431,196
Total Plant Overhead	7.00% TMC	$817,390	$392,635
		=========	=========
Total Manufacturing Cost (TMC)		$11,676,996	$5,609,077
Manufacturing Cost per Packaging Unit		**$12.863**	**$18.697**

Appendix B

Manufacturing Cost, Creamed Ground Beef
War Time Scenario

		Unlimited Prod	Limited Prod
Direct Production Cost		**Annual Cost**	
Raw Materials		$26,595,377	$16,275,344
Tray Packaging Cost		$9,107,739	$5,573,585
Carton & Case Cost		$7,487,196	$4,581,875
Total Annual Labor Cost		$1,842,048	$1,127,262
Utilities		$247,927	$151,721
		=========	=========
Total Direct Production Cost		$45,280,287	$27,709,788
Fixed Charges			
Depreciation	10.00% FCI	$1,286,253	$1,286,253
Maintenance and Repair	6.00% FCI	$771,752	$771,752
Operating Supplies	1.00% FCI	$128,625	$128,625
Local Taxes	4.00% FCI	$514,501	$514,501
Insurance	1.00% FCI	$128,625	$128,625
Financing Cost	9.00% TCI	$1,361,914	$1,361,914
Rent			
		=========	=========
Total Fixed Charges		$4,191,670	$4,191,670
Total Plant Overhead	7.00% TMC	$3,723,696	$2,401,185
		=========	=========
Total Manufacturing Cost (TMC)		$53,195,653	$34,302,643
Manufacturing Cost per Packaging Unit		**$10.851**	**$11.434**

Manufacturing Cost, Sausage in Brine
War Time Scenario

		Unlimited Prod	Limited Prod
Direct Production Cost		**Annual Cost**	
Raw Materials		$25,985,695	$15,902,242
Tray Packaging Cost		$9,107,739	$5,573,585
Carton & Case Cost		$7,487,196	$4,581,875
Total Annual Labor Cost		$1,842,048	$1,127,262
Utilities		$247,927	$151,721
		=========	=========
Total Direct Production Cost		$44,670,605	$27,336,686
Fixed Charges			
Depreciation	10.00% FCI	$914,918	$914,918
Maintenance and Repair	6.00% FCI	$548,951	$548,951
Operating Supplies	1.00% FCI	$91,492	$91,492
Local Taxes	4.00% FCI	$365,967	$365,967
Insurance	1.00% FCI	$91,492	$91,492
Financing Cost	9.00% TCI	$968,736	$968,736
Rent			
		=========	=========
Total Fixed Charges		$2,981,555	$2,981,555
Total Plant Overhead	7.00% TMC	$3,586,722	$2,282,018
		=========	=========
Total Manufacturing Cost (TMC)		$51,238,882	$32,600,259
Manufacturing Cost per Packaging Unit		**$10.452**	**$10.867**

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Heat Penetration Studies

of

Creamed Ground Beef in Polymeric Tray

Part II

Technical Working Paper (TWP-216)

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Table of Content

1 Introduction

Since the inception of the Tray Pack Ration, the product has been packaged in a heavy metal tray shaped can with a double seamed metal lid and processed in non rotary, batch retort systems. Due to the declining supplier base for the metal tray can and lid and various problems with the interior coating of the cans, an alternative package was developed utilizing a polymeric tray body with a laminated foil and polymer lidstock. The change over to this particular container has a significant impact on the number of containers that can be processed in each retort batch. A larger foot print of the container flange and the requirement that the weight of each container needs to be supported by a racking mechanism rather than by stacking the containers on top of each other reduces the capacity approximately 33%.

The reduction in batch capacity can be offset, if the process cycle time can be reduced by the same percentage. This project investigates the impact of selected process and product parameters on the heat penetration rate of the product and the required process time to render the product commercial sterile.

2 Objective

Conduct a process study to determine the impact of sauce viscosity on the required retort cycle time to yield commercial sterile product.

3 Product and Package Description

Creamed Ground Beef, the product that was used in this study, complies with the Contract Technical Requirement dated January 11, 2000.

The precooked ground beef used for this study was manufactured by St James Gourmet, Farmingdate NY. The ground beef was partial precooked, frozen and packed in cryovac bags by the supplier for easier handling. The ground beef was re-blanched at the FMT facility to avoid excessive weight loss during the retort process and thinning of the sauce. Also, the precooking/blanching process removed excessive fat and juices, which otherwise might yield an unacceptable product.

Two different cream sauces were made according to the recommended formula in the product specification with the exception that the starch quantity was reduced from 6% to 5.5% (see table below). The two starches that were used for this experiment are: Purity W® and Thermtex®, both from National Starch, Bridgewater NJ. Two other main ingredients: "Dry Cream" and "Shortening" were manufactured by respectively Quality Ingredients, Burnsville MN (Quali-Cream 7211) and Kerry Inc, Beloit WI (NDX-112 V, Item No. I1529). Sauce formula II with Thermtex, had also Titanium dioxide (0.2%) to make the sauce less dark in a rotating retort process.

Ingredient	Sauce Formula I Code: **P-W**	Sauce Formula II Code: **T-T**
Water	83.10%	82.90%
Starch, Purity W	5.50%	0.00%
Starch, Thermtex	0.00%	5.50%
Shortening, powder	3.25%	3.25%
Onion Powder	1.50%	1.50%
Salt	1.50%	1.50%
Soup stock, dehydrated	0.75%	0.75%
Worchester sauce	0.25%	0.25%
Titanium dioxide	0.00%	0.20%
Pepper, White	0.15%	0.15%

Both Purity-W and Thermtex are modified food starches, the difference between the two starches is the temperature that is required to fully develop the starch structure. Purity-W develops its full viscosity at the batching temperature of 180 F, while Thermtex will partially develop its viscosity at batching temperatures and thus yielding a low initial viscosity sauce, allowing for fast heat penetration rates. Thermtex develops it's full viscosity during the retort process, providing approximately the same high final viscosity after the retort process than Purity-W. This starch is therefore ideally suited for many canned food systems where optimum heat penetration and high final viscosity are required.

The trays used in this experiment were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

4 Process Description:

Both cream sauces were made in a jacketed kettle, equipped with high speed mixer and scrape surface agitator using the following procedure:

1) Mix required quantity of starch in small quantity of cold water and mix vigorously to form a thin slurry.
2) Add remaining quantity of cold water to kettle.
3) Add Dry Cream to kettle and mix vigorously (speed setting: 2) till all dissolved.
4) Add remaining ingredients (except starch slurry) to kettle and mix while heating kettle till product reaches 180 F to 190 F. Use high heat setting
5) Add starch slurry and the final mixture should be heated to 180 F to 190 F and held at this temperature for 5 minutes. (Use low heat setting once 180 F is reached)
6) If product needs to be refrigerated, cool product to 90 F and pump into buckets. Label buckets with material ID and Lot Number. Place product in refrigerator.

The precooked ground beef was blanched at out facility to remove excessive fat and juices from the ground beef. The ground beef was then drained and mixed with the refrigerated cream sauce at a ration of 32 oz of ground beef to 60 oz of cream sauce.

The trays were filled to a net weight of 92 oz. The trays intended for heat penetration studies were equipped with a thermocouple that was placed in the middle of the tray and held in place by a 1.5" diameter spacer disk which was placed near the end of the thermocouple. The thermocouples used for the heat penetration study were manufactured by Ecklund-Harrison technology, Ft.Myers FL. and are identified as "Needle Type Thermocouple", (4-3/4" long), type CNL.

The filled trays were placed in the sealing carriers of the Raque Heat Sealer and sealed at a speed of approximately 8 trays/min. while seal conditions were maintained at 412 F for 6.5 seconds. The vacuum condition was a variable in this study. and was controlled by a vacuum timer that opened a vacuum valve for a preset duration. A vacuum time of 1.0 seconds resulted in an approximate vacuum of 20" Hg in the sealing chamber, yielding trays that had a pre-retort residual gas level of less then 175 cc. A vacuum time of 0.17 seconds resulted in an approximate vacuum of 10" Hg in the sealing chamber, yielding trays that had a pre-retort residual gas level of approximately 350 cc.

The sealed trays with thermocouples were loaded "face up" in the front cage of a Stock 1100, four cage Rotomat, using polymeric tray racks specifically designed for this tray. The trays were placed in layers 4 through 9 (two cans per layer). Additional trays without thermocouples were also placed within these layers and retorted to yield samples for post process product evaluation. All remaining rack pockets were filled with ballast trays (trays filled with water). The other three cages of the retort were filled with ballast boxes. The polymeric tray racks used in this study were manufactured by Stock America, Grafton, WI and are identified as "7333A". The design features of this rack allowed the trays to be loaded either "face up" or "face down", and the tray are locked into the pocket so that they can be rotated during the retort process without creating abrasion defects.

Two retort programs were developed and used in this study. One program was designed for a static process. Program #20 processed the tray "up-side-down". The other program was designed for a rotational process. Program #23 rotated the trays at a speed of 15 rpm. Both retort programs used the same temperature and pressure profile. The temperature of the retort was set at 254 F during the Come Up Phase (S2) and at 252 F during the Hold Phase (S3). Copies of the retort programs can be found in the Appendix I.

The heat penetration data was collected during the process via a system supplied by Ellab Inc, Copenhagen DN. The main components of the system were a 16 channel slip ring assembly, an Analog/Digital converter (CMC) and Ellab CMC software, which had the ability to calculate the F_0 values on-line. The data was analyzed using Ellab's "Eval Basic" software, version 1.20.

The heating phase of the retort process was terminated after all thermocouples had reached an F_0 value of greater or equal to 6.0 min. The cooling phase was terminated after all thermocouples indicated a temperature lower or equal to 120 F.

5 Full Factorial Experimental Design:

A full factorial design was adopted to investigate the effect of vacuum applied during sealing and retort rotation speed. Post Retort Residual Gas, Post Retort Product Consistency and the required Cooking Time (CT) of the product were measured/calculated as response variables.

Static Mode:

Parameters	**Levels**		**Response**
Product Formulation	Regular Starch (P-W)	High Temperature Starch (T-T)	Residual Gas, Product Consistency & CT (Cook Time)
Vacuum applied	20" (targeting 150 cc residual gas)	10" (targeting 350 cc residual gas)	

Rotational Mode:

Parameters	**Levels**		**Response**
Product Formulation	Regular Starch (P-W)	High Temperature Starch (T-T)	Residual Gas, Product Consistency & CT (Cook Time)
Vacuum applied	20" (targeting 150 cc residual gas)	10" (targeting 350 cc residual gas)	

The total number of experiments required to determine the main effects and interactions for the above two factors was 4 (=2^2) for each mode. Each experiment would contain 10 to 12 trays with thermocouples and at least one additional tray without thermocouple. Each experiment would be repeated at least once.

6 Data Analysis

Using Ball's heat penetration assumptions, each thermocouple lead data was analyzed for the typical heating factors[1] such as *jh, fh, xbh, f2*. These heating factors were then used to calculate the required Cook Time to reach a Lethality of F_0= 6.0 min, using a Retort Temperature of 250 F and an Initial Product Temperature of 80 F. The Cook Time variable was then used for statistical analysis.

Each tray with a thermocouples was also analyzed for post-retort residual gas level. This measurement was performed by opening the tray below water and capturing the "free air" in an inverted graduate cylinder. This post-retort residual gas data was the used for statistical analysis.

One of the trays without thermocouple was analyzed for product consistency. This measurement was done by heating the product, draining the sauce from the ground beef in a #7 sieve and measuring the consistency in a Bostwick Consistometer. Due to the limited data, data is reported "as is" and no statistical analysis could be performed.

All statistical analysis was based on the outputs from SAS software[4], SAS Institute Inc and StatGraphics version 5.0[5]. The statistical procedures used in the analysis were General Linear Model (GLM), Multifactor ANOVA, and the Univariate procedures.

6.1 Refinement of Data

The analysis procedure started by refining the raw data by removing the outliers through two-stage refinement process. The first stage removed the outliers based on residual gas model. Observations with absolute standardized residual values (based on Residual Gas model) greater than 2 were removed from the data file.

> **Note:** Outliers due to residual gas might have been caused by variation during the sealing process, either due to a sticking valve or a leaking seal chamber. It was

deemed prudent to remove these outliers in order to minimize the impact of excessive variation in residual gas on subsequent analysis.

During the second stage, removing outliers based on the Cook Time model further refined the output from the first stage. The same criteria was used to discard observation with absolute standardized residual values (based on the Cook Time model) greater than 2.

> **Note:** The exact location of the thermocouple within container can have a significant effect on the heat penetration rate. Outliers in the Cook Time model might have been caused by shifting of spacer disk during packaging and retort loading, causing an improperly located thermocouple. It was deemed prudent to remove these outliers in order to minimize the impact of incorrect located thermocouples.

The refined data was then used for subsequent analysis of variance and is reported in the following section.

> **Note:** It should be noted that none of the conclusions reached in the analysis would have been reversed if the outliers would not have been removed.

6.2 Results

6.2.1 Static Mode

6.2.1.1 Residual Gas Analysis:
The data was first analyzed for post retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Starch and Vacuum was also significant at 99% confidence level, indicating the means for the different starch types and vacuums are not equal.
- The interaction between Starch Types and Vacuum was significant at 99% confidence level.

Multiple comparison test (Tukey Test) was used to compare between the two starch types and the two levels of vacuum. The test indicated, that the vacuum applied during sealing had a significant impact on the residual gas level inside the tray after retorting. However, the test also indicated (at 0.05 significance level) that the post retort Residual Gas value was significantly affected by the starch type. The residual gas level was significantly higher when using starch T-T. Because the trays were filled and sealed with a different product formulation, it can **not** be assumed that there would have been no significant difference between pre-retort residual gas levels inside the tray under the same vacuum conditions. Product formulation might have affected the headspace in the container and thus the pre retort residual gas level..

Tukey Grouping	Mean	N	Starch
A	268.6	30	T-T
B	199.3	42	P-W

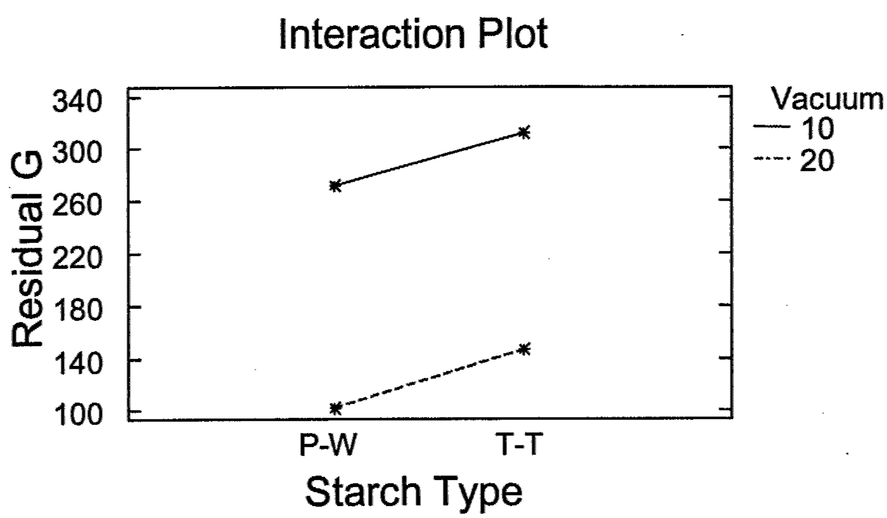
*Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Vacuum
A	334.7	32	10"
B	142.9	40	20"

*Means with the same letter are not significantly different.

Means Analysis per Treatment:

Starch Type	**Level of Vacuum**	**N**	**Residual Gas**			
			R-Square CV	**Mean**	**SD**	**CV**
P-W	10"	18	0.967	316.9	23.6	0.07
P-W	20"	24	0.083	111	14	0.13
T-T	10"	14		357.5	17.9	0.05
T-T	20"	16		190.8	20.6	0.11



6.2.1.2 Cook Time Analysis

The refined data was then analyzed for Cook Time using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Cooking Time).
- The F-test Starch Type was significant at 99% confidence level, indicating the means at the different Starch Types (P-W and T-T) are not equal.
- The F-test for Vacuum was significant at 99% confidence level, indicating the means at the different Vacuum Levels are not equal.
- The interaction between Starch Type and Vacuum was significant at 99% confidence level.

Multiple comparison test (Tukey Test) was used to compare between the different levels of vacuum. The output from the test (at 0.05 significance level) indicated that we have a lower CT value (faster heating) when the tray was processed sealed under a 20" vacuum (~150 cc) and when using Starch P-W.

Tukey Grouping	Mean	N	Starch
A	85.8	30	T-T
B	80.4	42	P-W

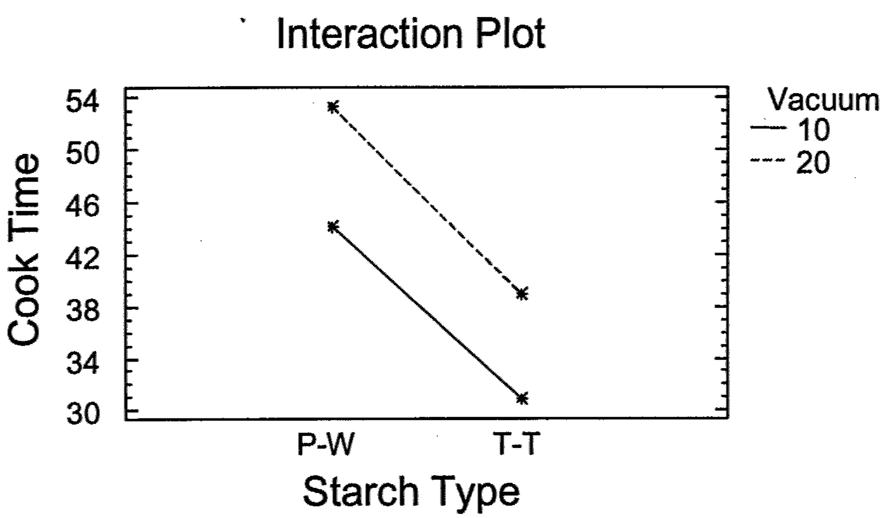
Tukey Grouping	Mean	N	Vacuum
A	89.8	32	10"
B	78.0	40	20"

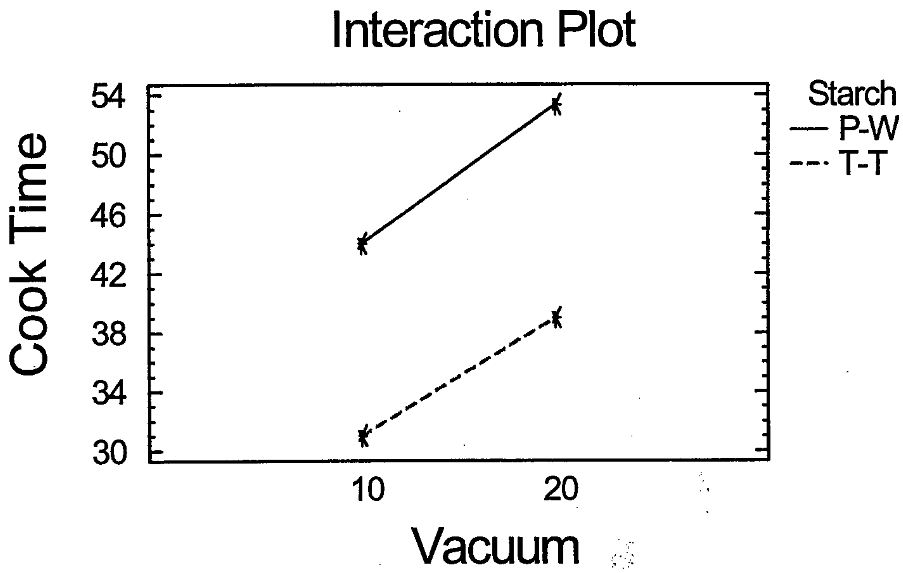
*Means with the same letter are not significantly different.

The data was then analyzed for the mean value per treatment (combination of Starch Type and Vacuum). As one can see from the table below and from the accompanying graph that Starch T-T with a low vacuum level (10") results in the longest Cook Time while Starch P-W with a high vacuum level (20") results in the shortest Cook Time.

6.2.1.2.1 Means Analysis per Treatment:

Starch Type	Level of Vacuum	N	CT			
			R-Square CV	Mean	SD	CV
P-W	10"	18	0.905	86.6	2.8	0.03
P-W	20"	24	0.028	75.8	1.9	0.02
T-T	10"	14		93.8	2.1	0.02
T-T	20"	16		78.7	2.4	0.03



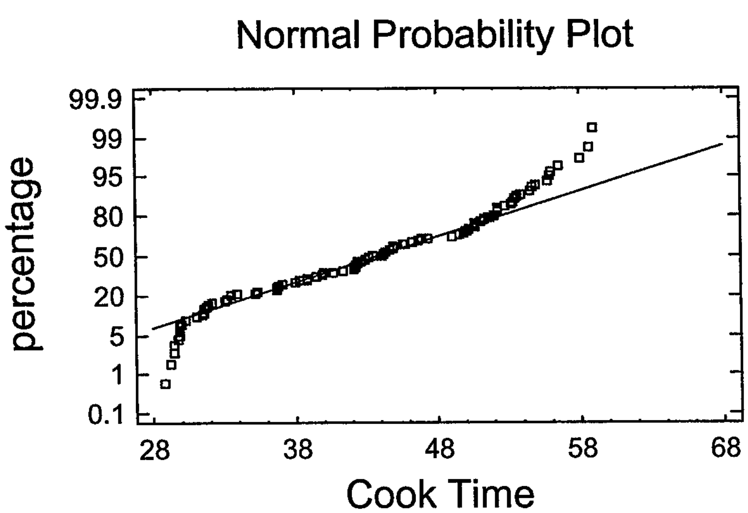


6.2.1.3 Model Assessment:

The R-Square value=0.90 in the ANOVA Table is evidence of a good fit is provided by the model. This value indicates that 90% of the variability in CT can be explained when Starch Type and Vacuum level are used as independent variables.

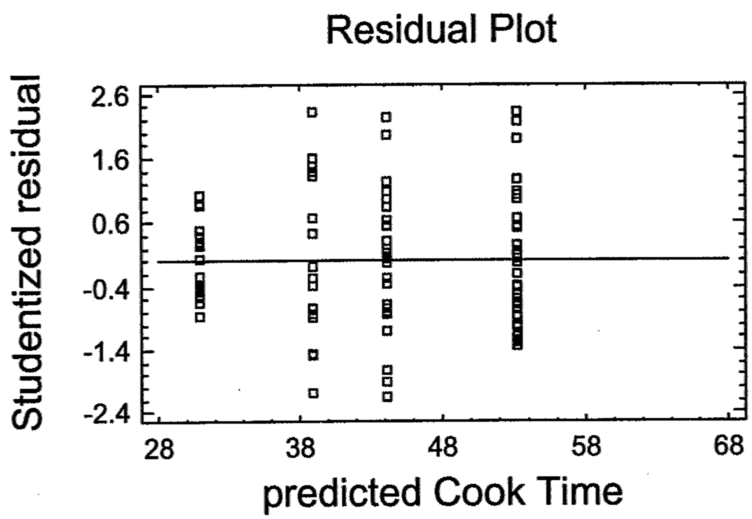
Accessing Normality:

The value of 0.89 for Shapiro-Wilk test and Normal Probability Plot below support the assumption of normality.



Accessing of Equality of Variance:

The Plot of Studentized Residual * Predicted CT shows a plot of residuals vs. predicted values of CT . Based on this plot, there is no strong evidence for unequal variances and for outliers. This means that our methodology for refining the data was successful.



6.2.2 Dynamic Mode:

6.2.2.1 Residual Gas Analysis:

The data was first analyzed for post retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Starch Type and Vacuum was also significant at 99% confidence level, indicating the means for the different starch types and vacuums are not equal.
- The interaction between Starch Type and Vacuum was not significant at 95% confidence level.

Multiple comparison test (Tukey Test) was used to compare between the two starch types and the two levels of vacuum. The test indicated, that the vacuum applied during sealing had a significant impact on the residual gas level inside the tray after retorting. However, the test also indicated (at 0.05 significance level) that the post retort Residual Gas value was significantly affected by the starch type. The residual gas level was significantly higher when using starch T-T. Because the trays were filled and sealed with a different product formulation, it can **not** be assumed that there would have been no significant difference between pre-retort residual gas levels inside the tray under the same vacuum conditions. Product formulation might have affected the headspace in the container and thus the pre retort residual gas level..

Tukey Grouping	Mean	N	Starch
A	236.2	37	T-T
B	176.1	55	P-W

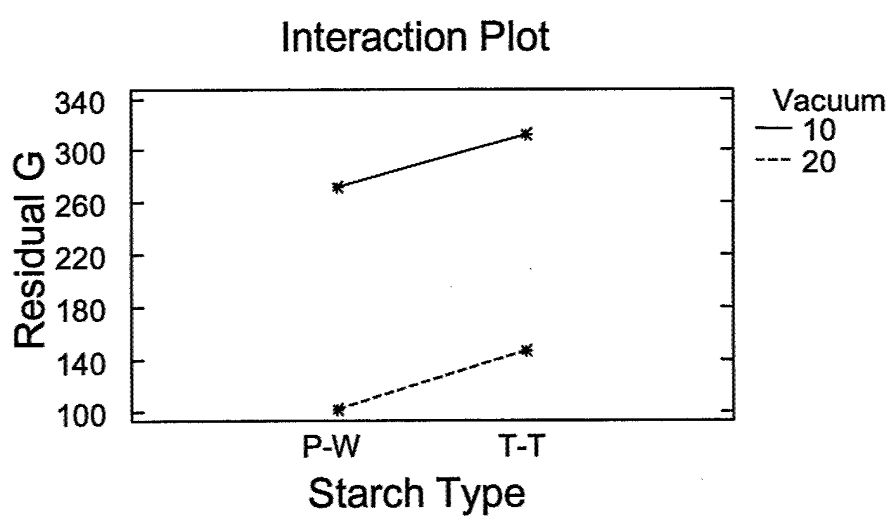
*Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	Vacuum
A	290.1	44	10"
B	117.8	48	20"

*Means with the same letter are not significantly different.

Means Analysis per Treatment:

Starch Type	Level of Vacuum	N	Residual Gas			
			R-Square CV	Mean	SD	CV
P-W	10"	24	0.963	271.4	18.7	0.07
P-W	20"	31	0.088	102.2	14.0	0.14
T-T	10"	20		312.5	21.7	0.07
T-T	20"	17		146.3	16.7	0.11



6.2.2.2 Cook Time Analysis

The refined data was then analyzed for Cook Time using a multifactor ANOVA analysis. Summary data, obtained from the SAS output can be found in Appendix-III. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Cooking Time).
- The F-test Starch Type was significant at 99% confidence level, indicating the means at the different Starch Types (P-W and T-T) are not equal.
- The F-test for Vacuum was significant at 99% confidence level, indicating the means at the different vacuum levels are not equal.
- The interaction between Starch Type and Vacuum was not significant at 95% confidence level.

Multiple comparison test (Tukey Test) was used to compare between the different levels of vacuum. The output from the test (at 0.05 significance level) indicated that we have a lower CT value (faster heating) when the tray was processed sealed under a 10" vacuum (~350 cc) and when using Starch T-T.

Tukey Grouping	Mean	N	Starch
A	34.6	37	T-T
B	49.3	55	P-W

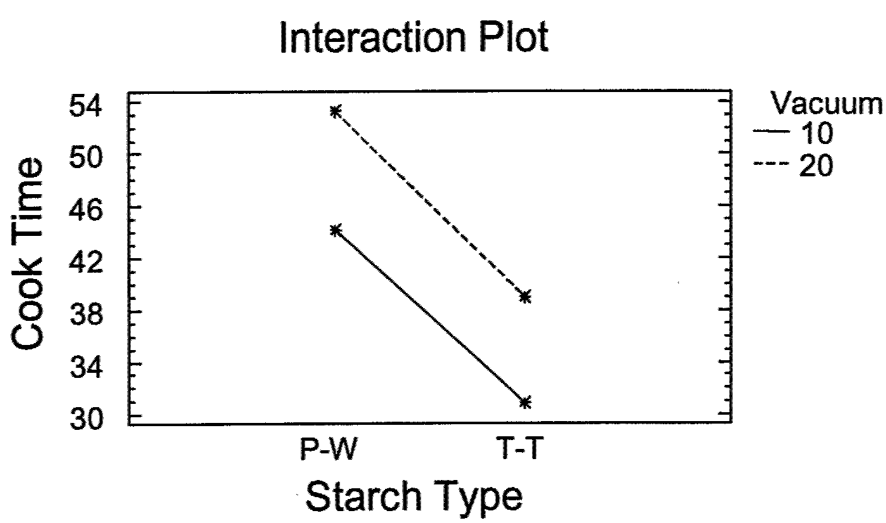
Tukey Grouping	Mean	N	Vacuum
A	38.1	44	10"
B	48.2	48	20"

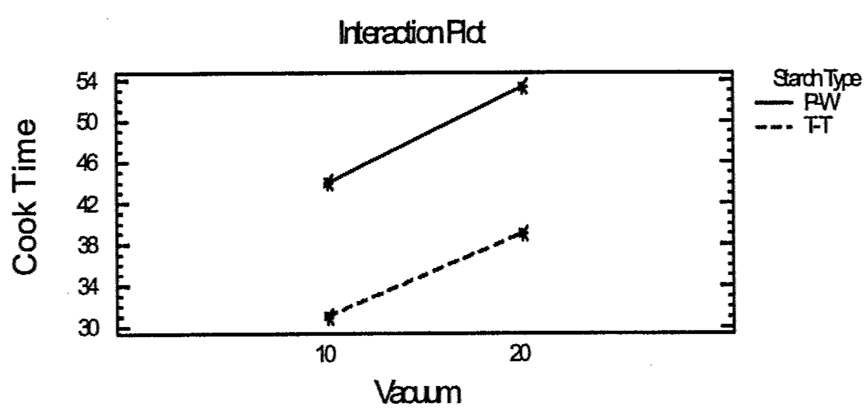
*Means with the same letter are not significantly different.

The data was then analyzed for the mean value per treatment (combination of Starch Type and Vacuum). As one can see from the table below and from the accompanying graph that Starch T-T with a low vacuum level (10") results in the shortest Cook Time while Starch P-W with a high vacuum level (20") results in the longest Cook Time.

6.2.2.2.1 Means Analysis per Treatment:

Starch Type	Level of Vacuum	N	CT			
			R-Square CV	Mean	SD	CV
P-W	10"	24	0.917	44.1	2.8	0.06
P-W	20"	31	0.059	53.3	2.6	0.05
T-T	10"	20		30.9	1.4	0.04
T-T	20"	17		38.9	3.2	0.08



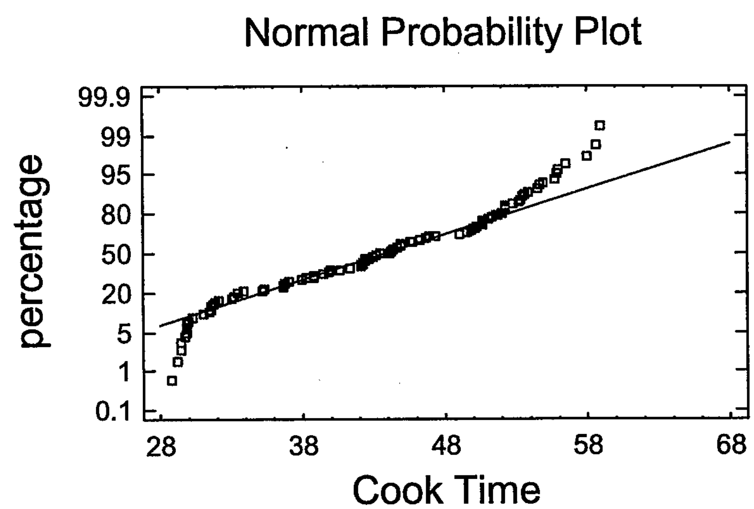


6.2.2.3 Model Assessment:

The R-Square value=0.92 in the ANOVA Table is evidence of a good fit is provided by the model. This value indicates that 92% of the variability in CT can be explained when Starch Type and Vacuum level are used as independent variables.

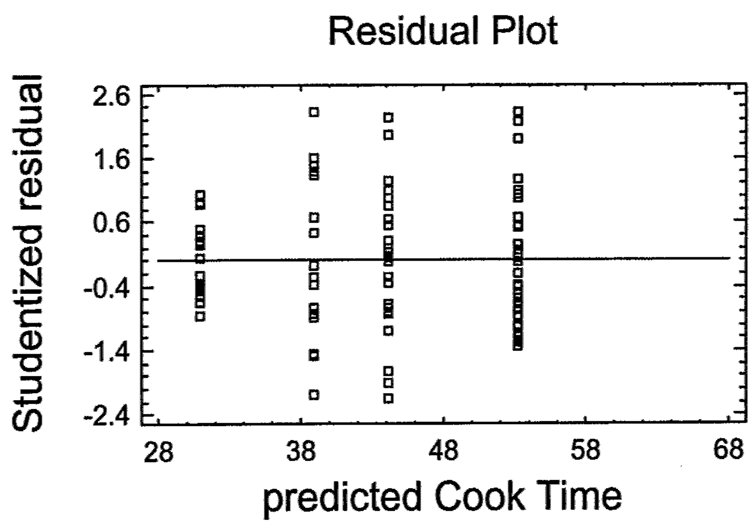
Accessing Normality:

The large value of 0.92 for Shapiro-Wilk test and Normal Probability Plot below support the assumption of normality.



Accessing of Equality of Variance:

The Plot of Studentized Residual * Predicted CT shows a plot of residuals vs. predicted values of CT . Based on this plot, there is no strong evidence for unequal variances and for outliers. This means that our methodology for refining the data was successful.


Residual Plot
Studentized residual
2.6
1.6
0.6
-0.4
-1.4
-2.4
28
38
48
58
68
predicted Cook Time

6.2.3 Comparisons of Static and Dynamic Retort Processing

6.2.3.1 Residual Gas

It was observed that there was a significant reduction in post retort residual gas level when one switches from static (program 20) to dynamic (program 23) retort processing. It is hypothesized that more air is "consumed" by, or more air incorporated into the product during a rotational retort process when more product is exposed to the "headspace" inside the can.

Program	Vacuum [inches Hg]	Post Process Residual Gas [cc]	
		P-W	T-T
Static	10	317	358
	20	111	191
Dynamic	10	271	313
	20	102	146

6.2.3.2 Product Color

The sauce color darkened significantly during rotational retort processing. However, samples submitted to The US Army Natick Soldier Center, Group Ration Team at Natick of Sauce Formula I were still rated as "acceptable". The darkening of the sauce color can be compensated by using "titanium dioxide" in the sauce formulation which was used in Sauce Formula II. Samples of this product still have to be evaluated by The US Army Natick Soldier Center, Group Ration Team.

6.2.3.3 Product Consistency

Rotational retort processing had a significant impact on the consistency of the product after retorting as can be seen in the table below. Consistency is measured by the distance the sauce travels during a 10 second time frame. Therefore rotational retort process leads to a thinner sauce. Samples submitted to The US Army Natick Soldier Center, Group Ration Team at Natick were rated as "acceptable"

Program	Vacuum [inches Hg]	Brookfield Viscosity Sauce before retorting [cP] [1]	Consistency [cm/10 sec]
20, Sauce Formula I	10	21,400	4.3
	20	21,400	4.4
20, Sauce Formula II	10	7,200	5.0
	20	7,200	5.0
23, Sauce Formula I	10	21,400	6.4
	20	21,400	7.1
23, Sauce Formula II	10	7,200	4.8
	20	7,200	4.7

[1)] Brookfield Digital Viscometer, model RVTDV-I, spindle #5, 10 rpm

7 Conclusions

The statistical analysis indicate that:

- Post retort residual gas is affected by the formulation used and by the retort process applied
- The calculated cook time based on heating factors is significantly impacted by the vacuum condition/residual gas inside the tray, by the retort rotation, and by the type starch used in the sauce formulation
- The slowest formulation, packaging and retort condition is a high temperature starch packed in a low vacuum condition and processed in a static mode
- The fastest formulation, packaging and retort condition is a high temperature starch packed in a low vacuum condition and processed in a rotational mode.
- Use of a high temperature starch, eg a starch that builds it's viscosity during the retort cook cycle, is most desirable when a rotational retort process is being considered.
- Relaxation of the product specification has economic benefits when a rotational retort process is being considered as long as it can be established that the quality of the product is not negatively affected.

8 References

1. Stumbo, C. R. (1973), Thermobacteriology in Food Processing, 2nd edition. Orlando: Academic Press, Inc.
2. Hicks, C. R., and Turner, Jr., K. V. (1999), Fundamental Concepts in the Design of Experiments, 5th edition. New York: Oxford University Press, Inc.
3. Dean, A. and Voss, D. (1999), Design and Analysis of Experiments, New York: Springer-Verlag, Inc.
4. SAS/STAT (1990), User's Guide, Version 6, 4th ed., SAS Institute Inc., Cary, NC, USA.
5. STATGRAPHICS Plus (2000), A Manugistics Product, Version 5, Manugistics, Inc., Maryland, USA.
6. Heat Penetration Studies of Pork Sausage in Brine in Polymeric Tray, Technical Working Paper #213. Center for Advanced Food Technology, Rutgers, The State University of New Jersey.
7. Heat Penetration Studies of Creamed Ground Beef in Polymeric Tray, Technical Working Paper #214. Center for Advanced Food Technology, Rutgers, The State University of New Jersey

9 Attachments

Appendix I: Retort Programs

Appendix II: Data Analysis Static Retort Process

Appendix III: Data Analysis Rotational Retort Process

Appendix I

Retort Programs

Appendix II

Data Analysis Static Retort Mode

ICON 2000 Stock America
Retort Program Print

Program # 020 STP1022_DOWN Product # 000000000020 Cont. Size:Poly Tray
Program last changed: 12:03:47 PM 10/16/2000

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

#20

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	0	0	0	0	0
Position:	A	C	C	C	C	C	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV Vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

ICON 2000 Stock America
Retort Program Print

Program # 023 STP1022_15RP Product # 000000000023 Cont. Size:Poly Tray
Program last changed: 12:11:35 PM 10/16/2000

#23

Program Specific Alarm Tolerances:

	High	Low
PV Temp.:	0.0	0.0
SV Temp.:	0.0	0.0
Pressure:	0.0	0.0
Rotor Speed:	0	0

Step:	1	2	3	4	5	6	7
Phase:	HSV	S1	S2	S3	C1	C2	DRN
SV Temp:	260.0	0.0	0.0	0.0	0.0	240.0	240.0
PV Temp:	0.0	250.0	252.0	250.0	0.0	90.0	0.0
Temp Grad:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pressure:	30.0	30.0	30.0	30.0	25.0	15.0	0.0
Press Grad:	0.0	0.0	0.0	0.0	1.0	1.0	0.0
Rotation:	0	0	15	15	15	15	0
Position:	A	A	A	A	A	A	A
Phase Time:	0:0	1:45	10:15	1:00	0:0	1:00	4:00
Opn PV vnt:		100.0%					
Cold Water:					100%	100%	
Init Temp:				No			
Prog. Hold:	Yes	No	No	Yes	No	Yes	No
Contact C1:	Off	Off	Off	Off	Off	Off	Off
Contact C2:	Off	Off	Off	Off	Off	Off	Off
Contact C3:	Off	Off	Off	Off	Off	Off	Off
Contact C4:	Off	Off	Off	Off	Off	Off	Off
Contact C5:	Off	Off	Off	Off	Off	Off	Off

INITIAL TEMPERATURE TABLE

Init Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

TEMPERATURE DEVIATION TABLE

Dev. Temp	Hold Time
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0
0.0	0:0

Refined Data

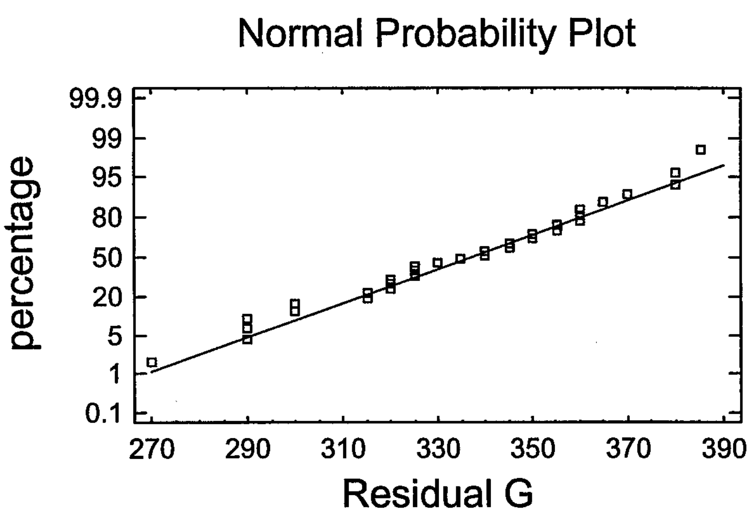
Run	Starch	Program	Vacuum	TC	Location	Residual G	F=6 time	Cook Time
R010131A	P-W	20	10	1	7	290	94.5	89.41
R010131A	P-W	20	10	4	4	350	94.5	88.83
R010131A	P-W	20	10	5	7	320	88	82.97
R010131A	P-W	20	10	7	9	335	89.5	84.54
R010131A	P-W	20	10	8	8	320	89	84.08
R010131A	P-W	20	10	9	5	340	93	87.32
R010131A	P-W	20	10	10	8	300	95	90.07
R010131A	P-W	20	10	13	4	325	90.5	84.46
R010131A	P-W	20	10	15	6	340	93	85.87
R010131A	P-W	20	10	16	9	360	97.5	91.32
R010214C	P-W	20	10	1	5	270	88	82.95
R010214C	P-W	20	10	4	8	290	90	87.26
R010214C	P-W	20	10	5	4	320	93.5	88.76
R010214C	P-W	20	10	7	5	290	91	87.49
R010214C	P-W	20	10	9	8	300	91.5	87.25
R010214C	P-W	20	10	13	7	325	85.5	82.79
R010214C	P-W	20	10	15	6	315	86.5	83.64
R010214C	P-W	20	10	16	6	315	95	89.94
R010516A	T-T	20	10	4	5	370	95.5	89.83
R010516A	T-T	20	10	6	7	360	101	94.05
R010516A	T-T	20	10	7	7	380	100	92.66
R010516A	T-T	20	10	8	4	360	102	95
R010516A	T-T	20	10	9	8	385	102	96.51
R010516A	T-T	20	10	13	6	345	100	93.28
R010516A	T-T	20	10	15	8	365	101	94.06
R010516A	T-T	20	10	16	6	380	100.5	95.14
R010523A	T-T	20	10	3	4	355	97.5	92.52
R010523A	T-T	20	10	6	6	355	103	96.74
R010523A	T-T	20	10	9	7	350	102	95.87
R010523A	T-T	20	10	10	5	330	95	89.94
R010523A	T-T	20	10	13	7	345	100	94.32
R010523A	T-T	20	10	16	5	325	100	94.04
R010201B	P-W	20	20	1	8	124	80	75.61
R010201B	P-W	20	20	3	8	104	78.5	74.02
R010201B	P-W	20	20	4	6	100	78	73.94
R010201B	P-W	20	20	5	4	106	79.5	74.82
R010201B	P-W	20	20	6	9	128	82.5	76.95
R010201B	P-W	20	20	7	6	102	80.5	75.57
R010201B	P-W	20	20	8	7	106	79	73.71
R010201B	P-W	20	20	9	7	94	80	75.28
R010201B	P-W	20	20	10	4	150	82	76.44
R010201B	P-W	20	20	13	5	88	78.5	73.5
R010201B	P-W	20	20	15	9	108	81.5	76.49
R010201B	P-W	20	20	16	5	114	80	75.57
R010215A	P-W	20	20	1	6	120	83	78.73
R010215A	P-W	20	20	3	7	126	83	79.43
R010215A	P-W	20	20	4	5	102	82.5	78.17
R010215A	P-W	20	20	5	5	110	78.5	73.44
R010215A	P-W	20	20	6	9	122	82.5	79.02

Run	Starch	Program	Vacuum	TC	Location	Residual G	F=6 time	Cook Time
R010215A	P-W	20	20	7	9	124	80	75.45
R010215A	P-W	20	20	8	4	98	78	73.88
R010215A	P-W	20	20	9	8	118	82.5	78.7
R010215A	P-W	20	20	10	4	104	78	73.62
R010215A	P-W	20	20	13	8	94	78.5	74.13
R010215A	P-W	20	20	15	6	120	82	76.72
R010215A	P-W	20	20	16	7	102	78.5	75.8
R010517A	T-T	20	20	1	8	215	85	80.33
R010517A	T-T	20	20	4	6	180	84	79.59
R010517A	T-T	20	20	6	7	224	83	78.49
R010517A	T-T	20	20	7	4	168	80	75.56
R010517A	T-T	20	20	9	5	186	83	78.92
R010517A	T-T	20	20	10	6	184	83	78.92
R010517A	T-T	20	20	13	5	230	82.5	78.45
R010517A	T-T	20	20	15	7	180	83.5	78.3
R010523B	T-T	20	20	1	4	194	84.5	81.13
R010523B	T-T	20	20	4	7	192	82.5	78.89
R010523B	T-T	20	20	5	5	160	79	75.96
R010523B	T-T	20	20	8	6	180	84	79.68
R010523B	T-T	20	20	10	8	204	87	82.45
R010523B	T-T	20	20	13	7	196	86.5	82.03
R010523B	T-T	20	20	15	4	200	77.5	73.18
R010523B	T-T	20	20	16	5	160	82	78.19

1- RESIDUAL GAS ANALYSIS

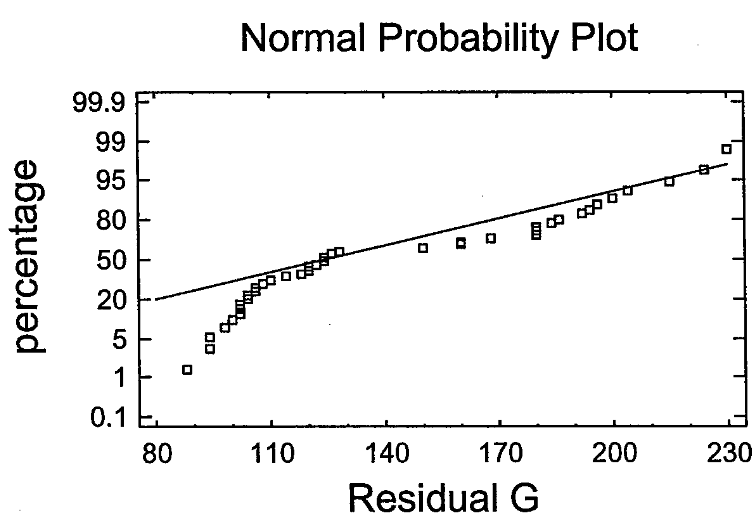
a.1 Probability Plot - Residual G (Program=20 & Vacuum=10)

Analysis Summary
Data variable: Residual G
Selection variable: Program=20 & Vacuum=10
32 values ranging from 270.0 to 385.0



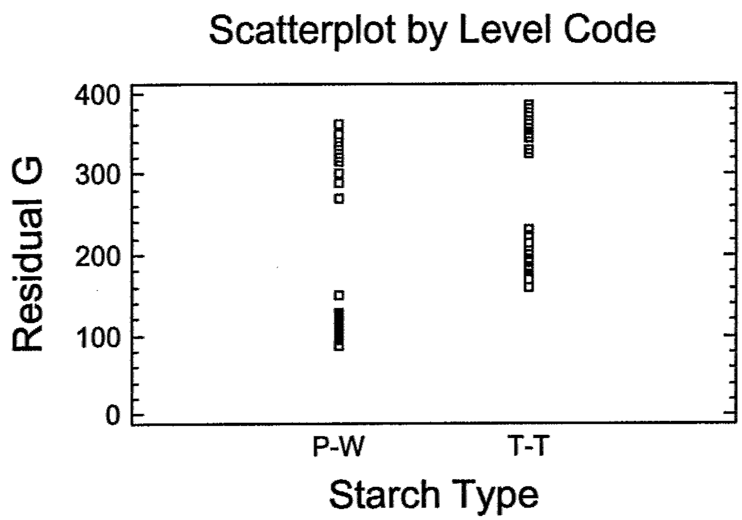
a.2 Probability Plot - Residual G (Program=20 & Vacuum=20)

Analysis Summary
Data variable: Residual G
Selection variable: Program=20 & Vacuum=20
40 values ranging from 88.0 to 230.0



b. Multifactor ANOVA - Residual G (last(72))

Analysis Summary
Dependent variable: Residual G
Factors:
  Starch Type
  Vacuum
Selection variable: last(72)
Number of complete cases: 72



Analysis of Variance

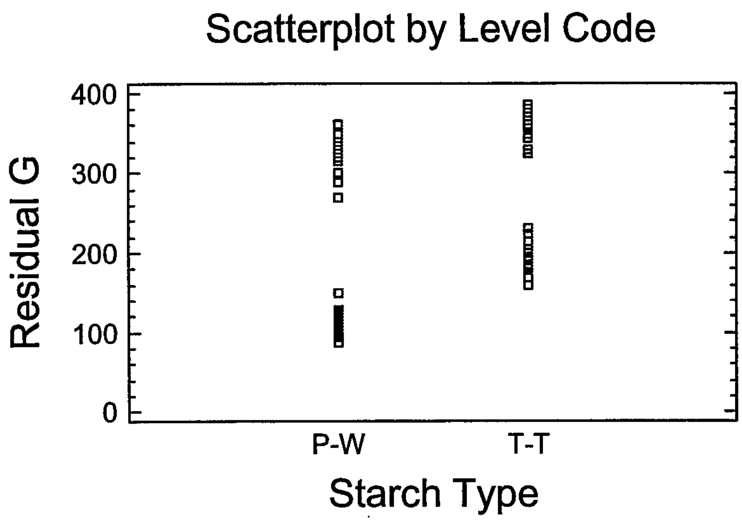
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	727844.0	3	242615.0	672.97	0.0000
Residual	24514.9	68	360.513		
Total (Corr.)	752359.0	71			

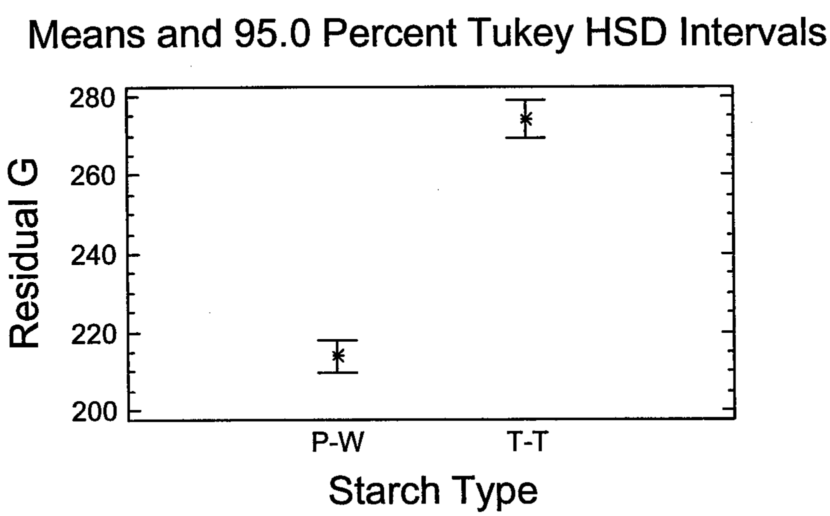
```
R-squared = 96.7416 percent
R-squared (adjusted for d.f.) = 96.5978 percent
Standard Error of Est. = 18.9872
Mean absolute error = 14.6543
Durbin-Watson statistic = 2.27092 (P=0.0641)
Lag 1 residual autocorrelation = -0.169631
```

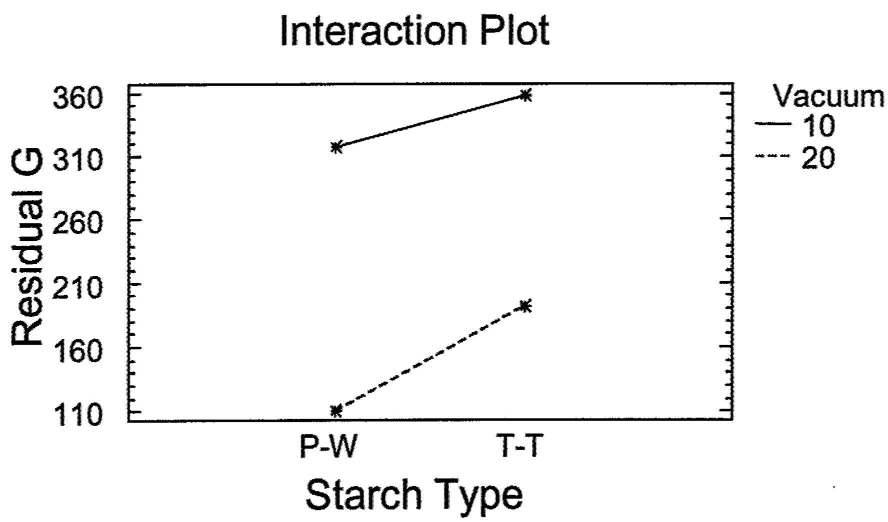
Analysis of Variance for Residual G - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Starch Type	62679.7	1	62679.7	173.86	0.0000
B:Vacuum	600710.0	1	600710.0	1666.26	0.0000
INTERACTIONS					
AB	6667.11	1	6667.11	18.49	0.0001
RESIDUAL	24514.9	68	360.513		
TOTAL (CORRECTED)	752359.0	71			

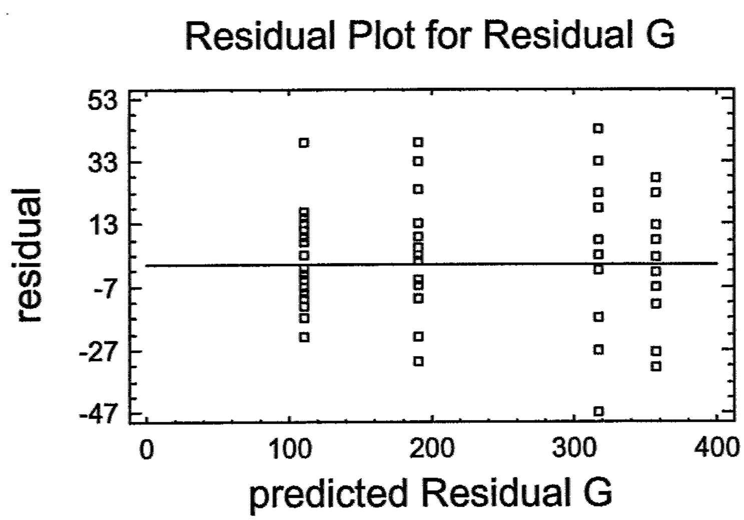
All F-ratios are based on the residual mean square error.


Scatterplot by Level Code
Residual G
400
300
200
100
0
P-W
T-T
Starch Type


Means and 95.0 Percent Tukey HSD Intervals
Residual G
280
260
240
220
200
P-W
T-T
Starch Type



Interaction Plot
360
310
260
210
160
110
Residual G
P-W
T-T
Starch Type
Vacuum
10
20

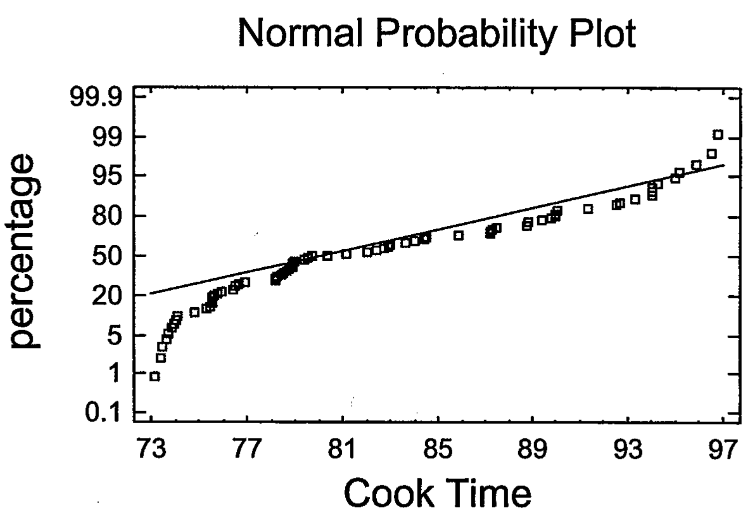


Residual Plot for Residual G
53
33
13
-7
-27
-47
residual
0
100
200
300
400
predicted Residual G

2. COOK TIME ANALYSIS

a.Probability Plot - Cook Time (Program=20)

Analysis Summary
Data variable: Cook Time
Selection variable: Program=20
72 values ranging from 73.18 to 96.74



b. Multifactor ANOVA - Cook Time (last(72))

Analysis Summary
Dependent variable: Cook Time
Factors:
  Starch Type
  Vacuum
Selection variable: last(72)
Number of complete cases: 72

Analysis of Variance

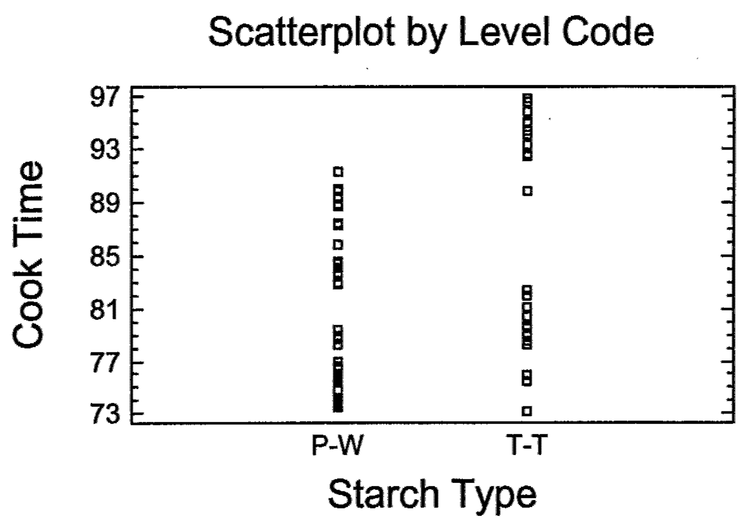
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	3411.35	3	1137.12	217.11	0.0000
Residual	356.158	68	5.23762		
Total (Corr.)	3767.51	71			

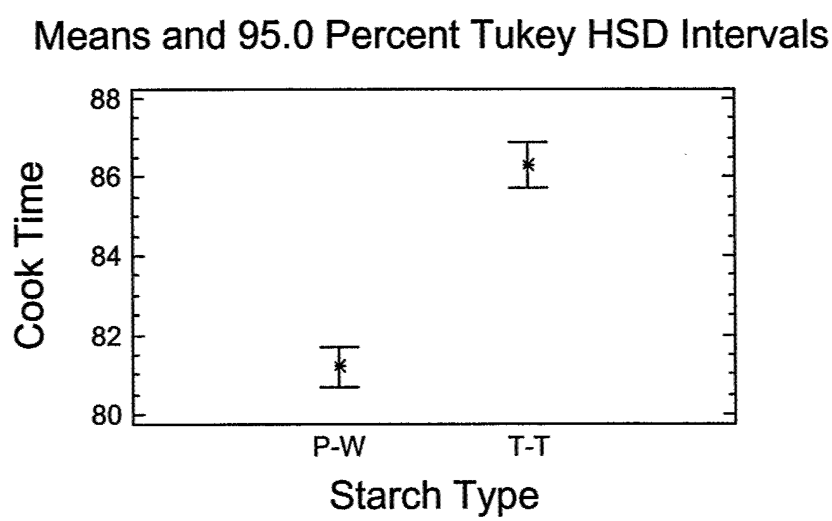
```
R-squared = 90.5466 percent
R-squared (adjusted for d.f.) = 90.1295 percent
Standard Error of Est. = 2.28859
Mean absolute error = 1.78601
Durbin-Watson statistic = 2.21637 (P=0.0993)
Lag 1 residual auto correlation = -0.119649
```

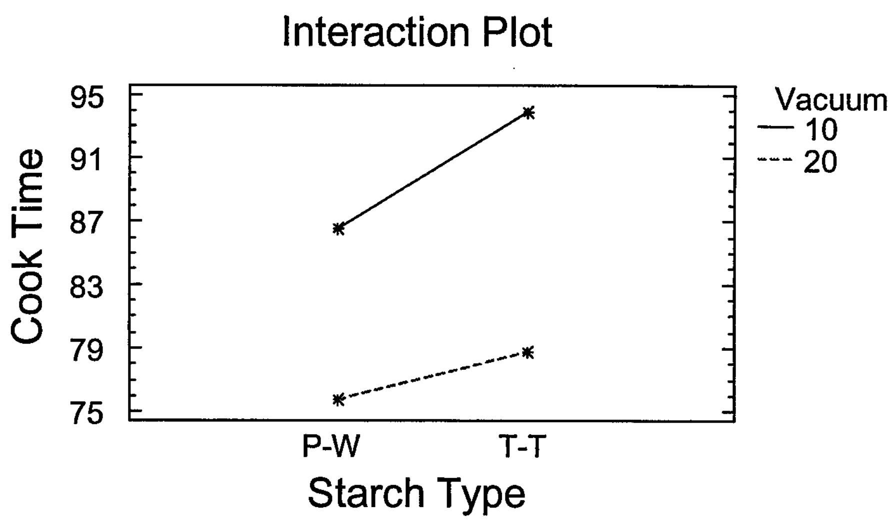
Analysis of Variance for Cook Time - Type III Sums of Squares

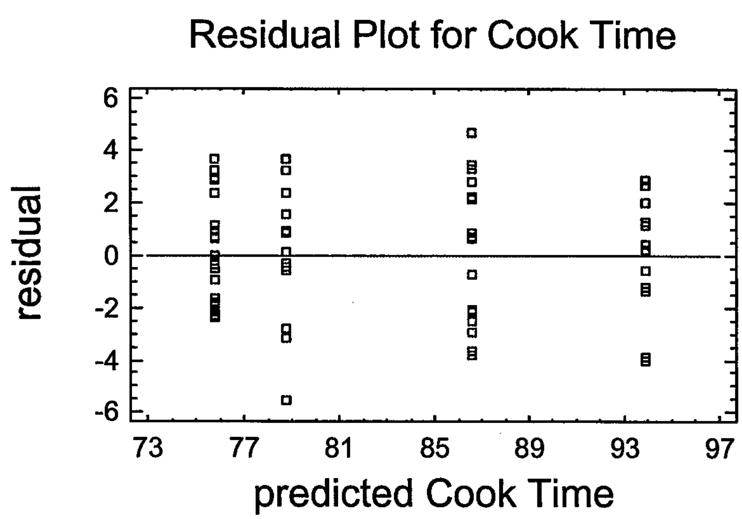
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Starch Type	450.897	1	450.897	86.09	0.0000
B:Vacuum	2905.85	1	2905.85	554.80	0.0000
INTERACTIONS					
AB	79.3534	1	79.3534	15.15	0.0002
RESIDUAL	356.158	68	5.23762		
TOTAL (CORRECTED)	3767.51	71			

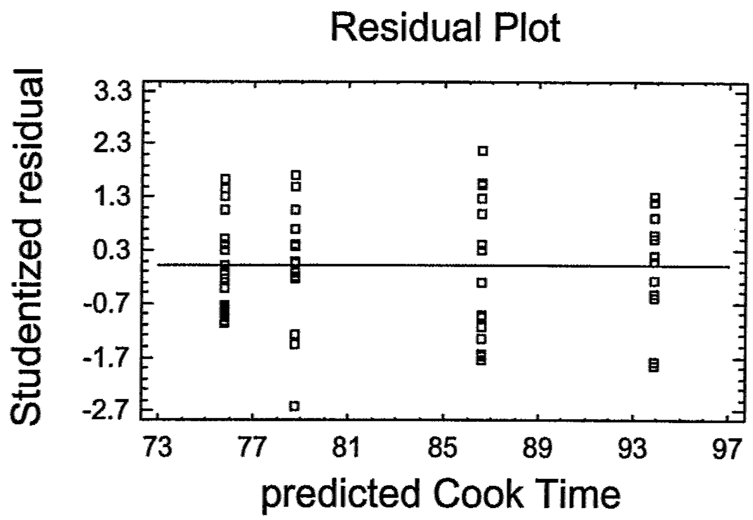
All F-ratios are based on the residual mean square error.






Interaction Plot
Cook Time
95
91
87
83
79
75
P-W
T-T
Starch Type
Vacuum
10
20


Residual Plot for Cook Time
residual
6
4
2
0
-2
-4
-6
73
77
81
85
89
93
97
predicted Cook Time



Residual Plot
Studentized residual
3.3
2.3
1.3
0.3
-0.7
-1.7
-2.7
73
77
81
85
89
93
97
predicted Cook Time

Appendix III: Data Analysis Rotational Retort Mode

Refined Data

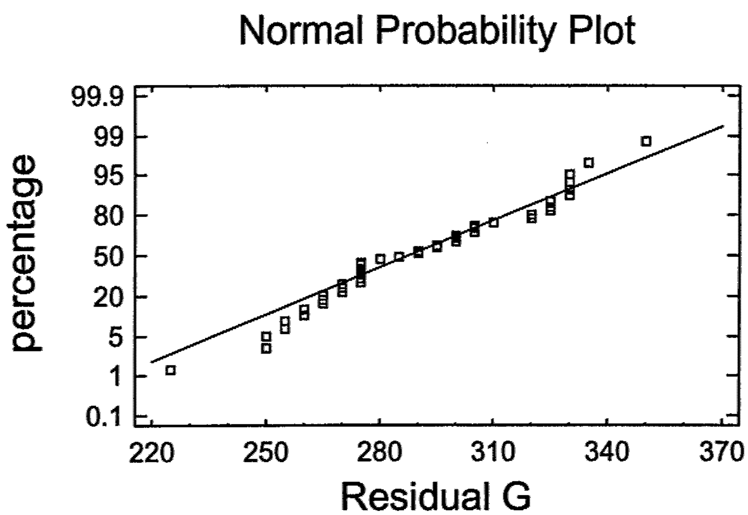
Run	Starch	Program	Vacuum	TC	Location	Residual G	F=6 time	Cook Time
R010126B	P-W	23	10	1	7	265	43.5	42.45
R010126B	P-W	23	10	3	6	280	47	44.27
R010126B	P-W	23	10	4	4	275	47.5	46.61
R010126B	P-W	23	10	5	5	265	46	47.28
R010126B	P-W	23	10	6	8	285	47	44.89
R010126B	P-W	23	10	7	7	270	48.5	49.66
R010126B	P-W	23	10	8	4	265	44	42.26
R010126B	P-W	23	10	9	8	270	47.5	46.9
R010126B	P-W	23	10	10	5	290	45	44.45
R010126B	P-W	23	10	13	9	225	48.5	49.02
R010126B	P-W	23	10	15	9	305	45	44.89
R010126B	P-W	23	10	16	6	275	45.5	44.62
R010131C	P-W	23	10	1	9	260	44.5	42.07
R010131C	P-W	23	10	3	4	275	41	38.82
R010131C	P-W	23	10	4	5	275	43	41.38
R010131C	P-W	23	10	5	7	255	44.5	43.23
R010131C	P-W	23	10	6	6	305	43	42.1
R010131C	P-W	23	10	7	8	290	47	46.28
R010131C	P-W	23	10	8	4	270	47	45.74
R010131C	P-W	23	10	9	9	250	45	43.48
R010131C	P-W	23	10	10	5	260	47.5	45.55
R010131C	P-W	23	10	13	7	300	41	39.41
R010131C	P-W	23	10	15	6	250	44.5	44.09
R010131C	P-W	23	10	16	8	255	42	39.8
R010516B	T-T	23	10	1	5	330	32.5	29.52
R010516B	T-T	23	10	4	8	320	34	31.89
R010516B	T-T	23	10	5	6	275	35	33.15
R010516B	T-T	23	10	6	8	325	33.5	32.16
R010516B	T-T	23	10	7	6	350	31.5	29.9
R010516B	T-T	23	10	8	4	310	31.5	29.88
R010516B	T-T	23	10	9	7	330	33.5	31.02
R010516B	T-T	23	10	10	4	300	34.5	33.5
R010516B	T-T	23	10	13	5	325	33.5	31.59
R010516B	T-T	23	10	16	7	335	35	33.13
R010517C	T-T	23	10	1	8	275	32	29.97
R010517C	T-T	23	10	3	7	295	31.5	29.71
R010517C	T-T	23	10	5	6	330	31.5	29.81
R010517C	T-T	23	10	6	8	330	32	30.3
R010517C	T-T	23	10	7	7	275	33	31.7
R010517C	T-T	23	10	8	4	320	32	29.45
R010517C	T-T	23	10	9	5	305	31	28.76
R010517C	T-T	23	10	10	4	295	31	29.26
R010517C	T-T	23	10	13	6	300	33.5	31.59
R010517C	T-T	23	10	16	5	325	33	31.51
R010124B	P-W	23	20	1	9	104	53.5	52.24
R010124B	P-W	23	20	3	6	104	61	58.68
R010124B	P-W	23	20	4	7	100	54.5	52.77
R010124B	P-W	23	20	5	8	82	61	58
R010124B	P-W	23	20	8	4	102	55	51.76
R010124B	P-W	23	20	9	7	90	54	53.92

Run	Starch	Program	Vacuum	TC	Location	Residual G	F=6 time	Cook Time
R010124B	P-W	23	20	10	5	86	52.5	50.65
R010124B	P-W	23	20	13	8	92	61	58.97
R010124B	P-W	23	20	15	5	122	51	50.05
R010201A	P-W	23	20	1	7	106	58.5	55.69
R010201A	P-W	23	20	3	6	112	55	53.34
R010201A	P-W	23	20	5	4	92	56	53.52
R010201A	P-W	23	20	6	8	118	53.5	51.34
R010201A	P-W	23	20	7	9	98	57.5	56.5
R010201A	P-W	23	20	8	8	132	52	50.25
R010201A	P-W	23	20	9	7	110	52	50.67
R010201A	P-W	23	20	10	6	102	54	53.25
R010201A	P-W	23	20	13	4	120	50	50.11
R010201A	P-W	23	20	15	5	114	49	49.86
R010201A	P-W	23	20	16	9	108	58	55.91
R010215C	P-W	23	20	1	8	140	51.5	51.56
R010215C	P-W	23	20	3	5	98	52.5	51.94
R010215C	P-W	23	20	4	7	88	53.5	52.3
R010215C	P-W	23	20	5	9	84	54.5	54.7
R010215C	P-W	23	20	6	6	90	53.5	53.65
R010215C	P-W	23	20	7	8	96	52	52.28
R010215C	P-W	23	20	8	5	88	57	56
R010215C	P-W	23	20	10	7	104	50.5	50.66
R010215C	P-W	23	20	13	5	88	54.5	54.59
R010215C	P-W	23	20	15	9	98	55.5	54.97
R010215C	P-W	23	20	16	4	100	52.5	51.11
R010516C	T-T	23	20	3	8	136	40.5	40.02
R010516C	T-T	23	20	3	5	154	40	38.28
R010516C	T-T	23	20	4	8	106	45	44.63
R010516C	T-T	23	20	5	4	158	41.5	38.78
R010516C	T-T	23	20	6	7	150	43.5	42.4
R010516C	T-T	23	20	9	7	140	44.5	42.65
R010516C	T-T	23	20	10	4	130	43.5	42.29
R010516C	T-T	23	20	13	6	136	44.5	42.89
R010517B	T-T	23	20	4	8	158	39	36.85
R010517B	T-T	23	20	5	6	142	38	36.72
R010517B	T-T	23	20	6	7	170	37.5	35.3
R010517B	T-T	23	20	7	4	160	35	33.82
R010517B	T-T	23	20	8	6	144	39.5	37.97
R010517B	T-T	23	20	9	4	130	41.5	40.67
R010517B	T-T	23	20	10	5	144	38.5	36.71
R010517B	T-T	23	20	13	5	176	37	35.24
R010517B	T-T	23	20	15	7	154	39	37.07

1. RESIDUAL GAS ANALYSIS

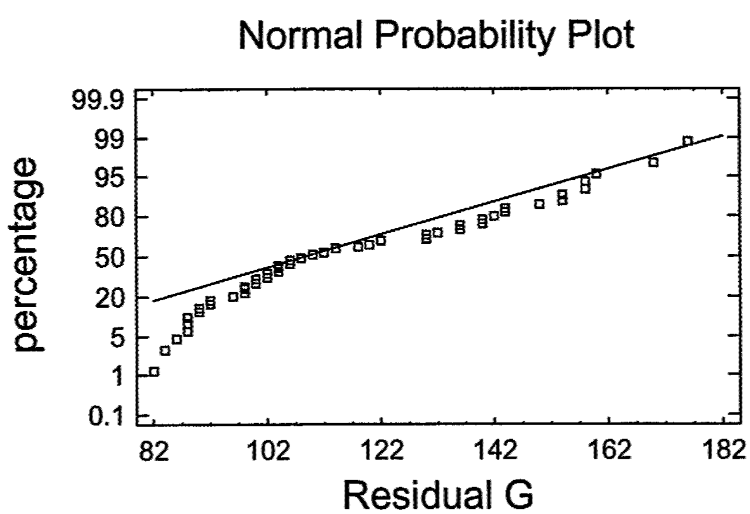
a.1 Probability Plot - Residual G (Program=23 & Vacuum=10)

Analysis Summary
Data variable: Residual G
Selection variable: Program=23 & Vacuum=10
44 values ranging from 225.0 to 350.0



a.2 Probability Plot - Residual G (Program=23 & Vacuum=20)

Analysis Summary
Data variable: Residual G
Selection variable: Program=23 & Vacuum=20
48 values ranging from 82.0 to 176.0



b. Multifactor ANOVA - Residual G (first(92))

Analysis Summary
Dependent variable: Residual G
Factors:
  Starch Type
  Vacuum
Selection variable: first(92)
Number of complete cases: 92

Analysis of Variance

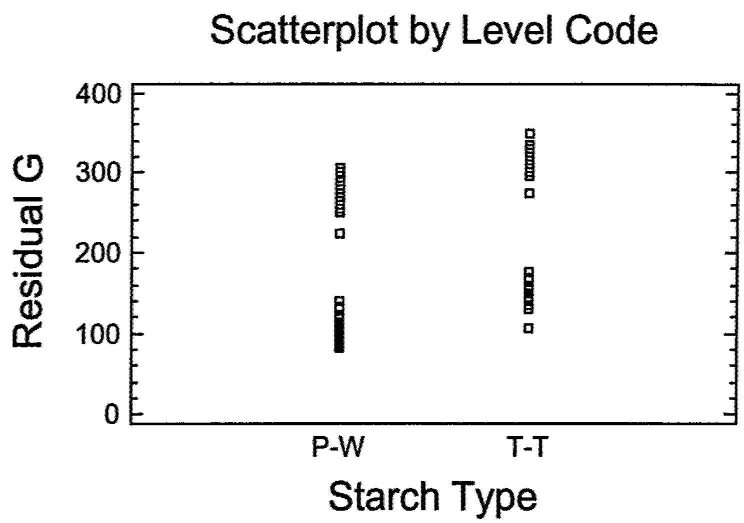
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	721147.0	3	240382.0	774.41	0.0000
Residual	27315.7	88	310.405		
Total (Corr.)	748462.0	91			

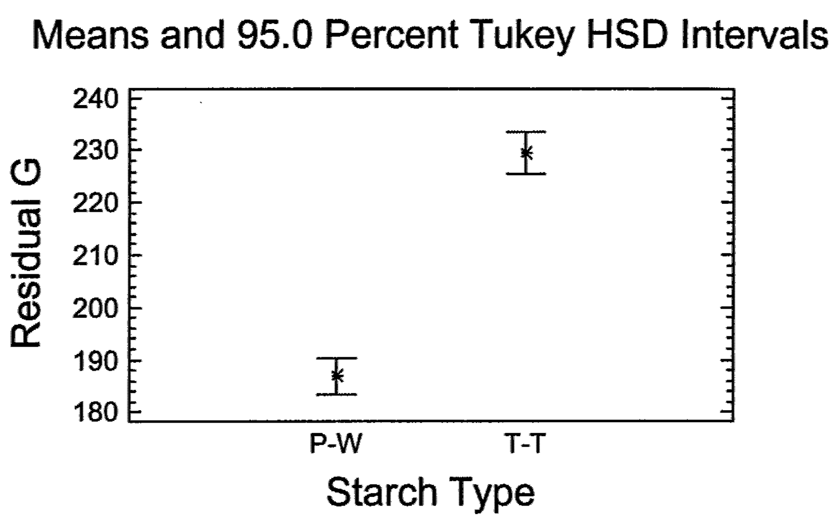
R-squared = 96.3504 percent
R-squared (adjusted for d.f.) = 96.226 percent
Standard Error of Est. = 17.6183
Mean absolute error = 13.6113
Durbin-Watson statistic = 2.26174 (P=0.0567)
Lag 1 residual autocorrelation = -0.132706

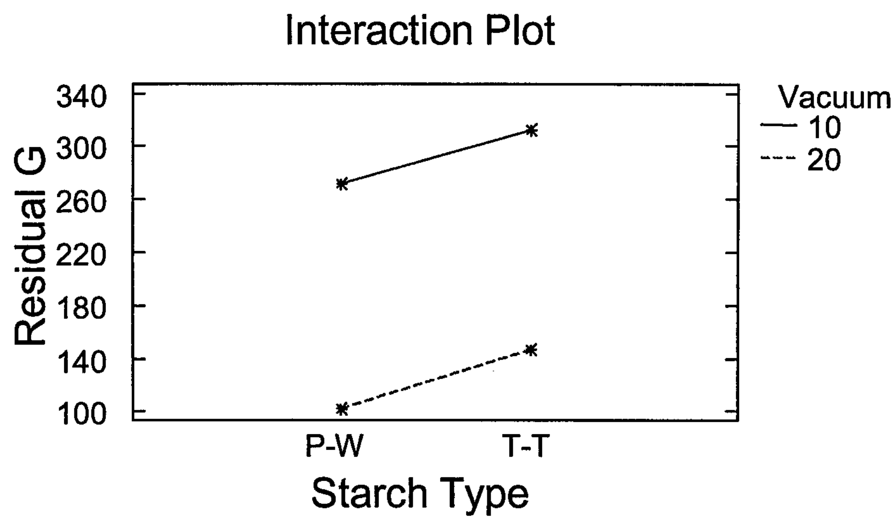
Analysis of Variance for Residual G - Type III Sums of Squares

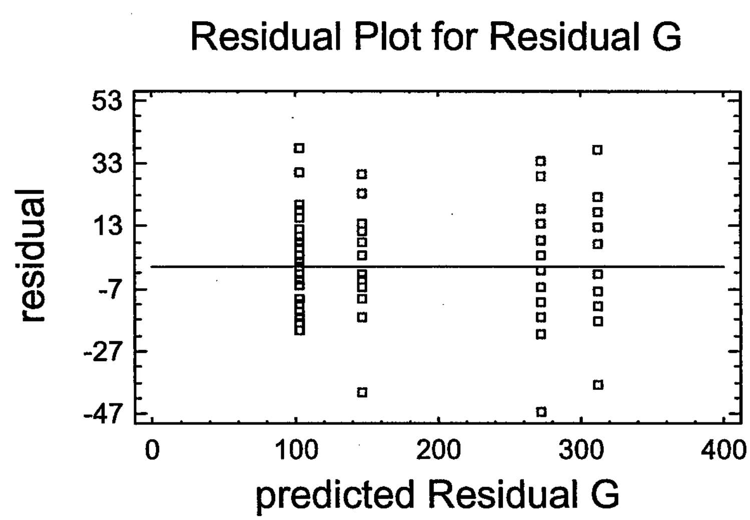
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Starch Type	39722.5	1	39722.5	127.97	0.0000
B:Vacuum	615607.0	1	615607.0	1983.24	0.0000
INTERACTIONS					
AB	53.1891	1	53.1891	0.17	0.6799
RESIDUAL	27315.7	88	310.405		
TOTAL (CORRECTED)	748462.0	91			

All F-ratios are based on the residual mean square error.


Scatterplot by Level Code
Residual G
400
300
200
100
0
P-W
T-T
Starch Type


Means and 95.0 Percent Tukey HSD Intervals
Residual G
240
230
220
210
200
190
180
P-W
T-T
Starch Type

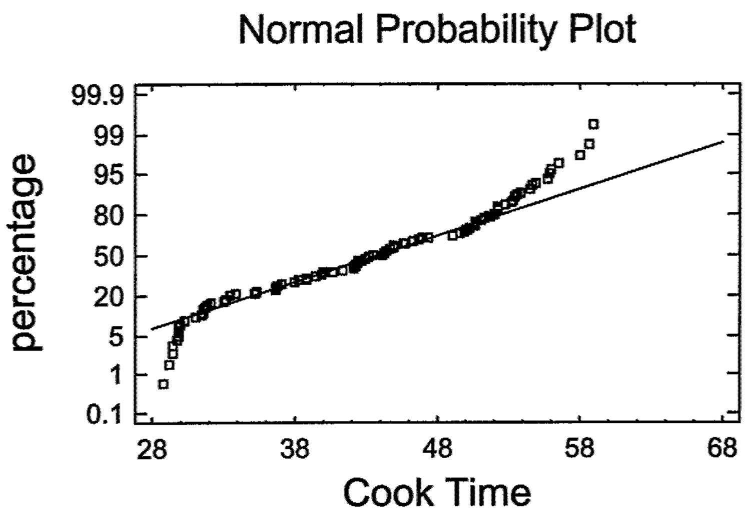

Interaction Plot
Residual G
340
300
260
220
180
140
100
P-W
T-T
Starch Type
Vacuum
10
20


Residual Plot for Residual G
residual
53
33
13
-7
-27
-47
0
100
200
300
400
predicted Residual G

2. COOK TIME ANALYSIS

a. Probability Plot - Cook Time (Program=23)

Analysis Summary
Data variable: Cook Time
Selection variable: Program=23
92 values ranging from 28.76 to 58.97



b. Multifactor ANOVA - Cook Time (first(92))

Analysis Summary
Dependent variable: Cook Time
Factors:
Starch Type
Vacuum
Selection variable: first(92)
Number of complete cases: 92

Analysis of Variance

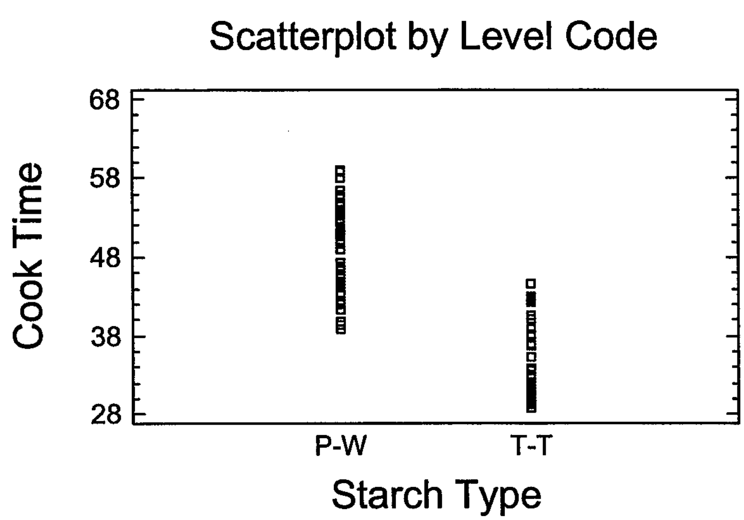
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	6495.68	3	2165.23	326.34	0.0000
Residual	583.877	88	6.63497		
Total (Corr.)	7079.56	91			

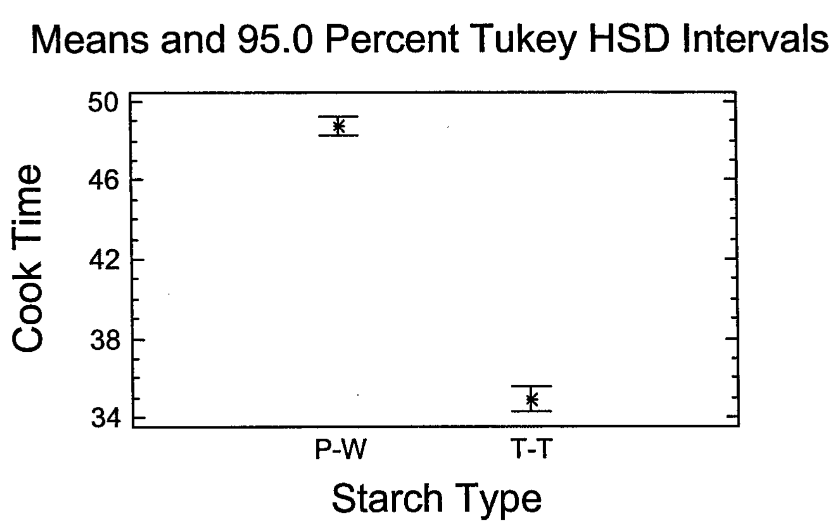
R-squared = 91.7526 percent
R-squared (adjusted for d.f.) = 91.4715 percent
Standard Error of Est. = 2.57584
Mean absolute error = 2.05001
Durbin-Watson statistic = 1.90111 (P=0.2138)
Lag 1 residual autocorrelation = 0.0439608

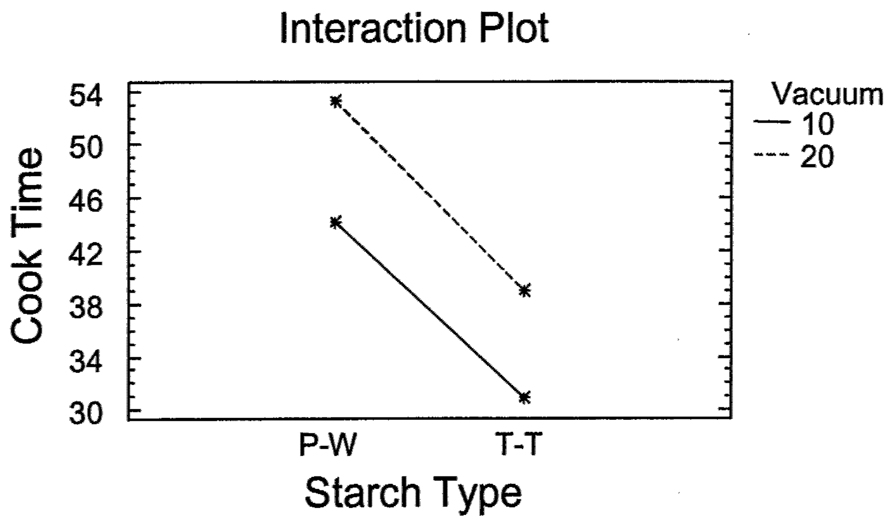
Analysis of Variance for Cook Time - Type III Sums of Squares

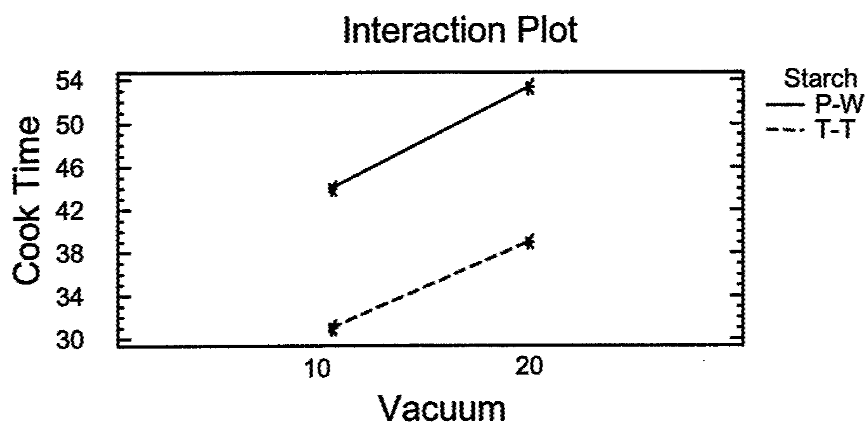
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Starch Type	4154.17	1	4154.17	626.10	0.0000
B:Vacuum	1618.58	1	1618.58	243.95	0.0000
INTERACTIONS					
AB	6.17337	1	6.17337	0.93	0.3374
RESIDUAL	583.877	88	6.63497		
TOTAL (CORRECTED)	7079.56	91			

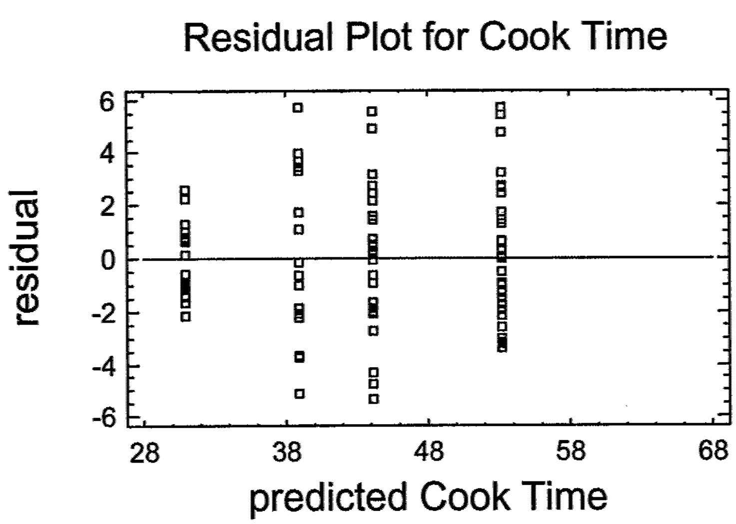
All F-ratios are based on the residual mean square error.






Interaction Plot
Cook Time
54
50
46
42
38
34
30
P-W
T-T
Starch Type
Vacuum
10
20


Interaction Plot
Cook Time
54
50
46
42
38
34
30
10
20
Vacuum
Starch
P-W
T-T


Residual Plot for Cook Time
residual
6
4
2
0
-2
-4
-6
28
38
48
58
68
predicted Cook Time

COMBAT RATION NETWORK
FOR
TECHNOLOGY IMPLEMENTATION

Filling & Sealing Studies of Pork Sausage in Polymeric Tray

Technical Working Paper (TWP-217)

Authors

H.B. Bruins, H.M. Fahmy, T.S. Kolodziej, Dr. E. Elsayed

Date:

September 2001

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Program Director

1 Introduction

Since the inception of the Tray Pack Ration, the product has been packaged in a heavy metal tray shaped can with a double seamed metal lid and processed in non rotary, batch retort systems. Due to the declining supplier base for the metal tray can and lid and various problems with the interior coating of the cans, an alternative package was developed utilizing a polymeric tray body with a laminated foil and polymer lid stock. The change over to this particular container has a significant impact on the Manufacturability of the product. Double rolled seams are replaced by fusion seals and contamination of seal area is more likely to result in seal defects. On the other hand, it is expected that the over all through put rate of a heat sealer can exceed that of a can seamer for the half steam table tray.

The sensitivity of seal contamination to seal defects, requires a thorough understanding of the interactions of process, product and packaging variables. This study documents these interactions and gives guidance to the producers in selecting process, product and packaging parameters that optimize the yield of the process and therefore minimize the cost of the product. This study also highlights the interactions the specification limits that might affect the manufacturability of the product.

2 Objective

Investigate the effect of selected product, process and packaging parameters in a filling and sealing process on the quality of the seal using "Pork Sausage Links in Brine".

3 Product and Package Description:

Pork Sausage Links in Brine used in this study complied with the Contract Technical Requirement dated January 11, 2000 with the exception that the water was used instead of brine.

The sausage links were manufactured by ASE Deli/Foodservice Company, St. Charles, IL. and are the same as used by current producers of "Pork Sausage Links in Brine" for Combat Feed Program. The sausage links were precooked by the supplier in order to avoid excessive weight loss during the retort process and each weighs approximately 20 grams before retorting. The sausage dimensions are approximately 3 " long and 1/2 to 3/4" in diameter. Each tray was filled with 72 Sausage Links which were placed in two layers, each layer containing three rows of 12 sausages.

The trays used in these experiments were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

4 Process Description

The trays were manual filled with sausage links, three rows/layer of approximately 12 sausages/row, two layers. The trays were then weight and its net weight adjusted to 1440 - 1460 gram by adding or subtracting a sausage link. The trays were then placed on the filling conveyor of the Raque Heat Seal line. The seals were wiped with alcohol to remove any "grease" stains in the seal area that might have occurred during the filling and handling process. The tray was conveyed to the Raque heat sealer and automatically loaded in the carriers of the sealer. Once in the carrier, water was added to the tray, by the Oden liquid filling system, to ensure that the net

weight target was met (90 oz or 96 oz). The Oden system used two pumps and two nozzles to deliver the required volume of water. Speed of the Oden system was adjusted to match the Tray line speed. The seals were then wiped by a single person with a paper towel. The tray was conveyed at a speed of 8 or 15 trays/min. while seal conditions were maintained at 412 F for 2.5 or 3.5 seconds. The vacuum condition was controlled by a vacuum timer that opened a vacuum valve for a preset duration. A vacuum time of 1.0 seconds resulted in an approximate vacuum of 20" Hg in the sealing chamber. A vacuum time of 0.2 seconds resulted in an approximate vacuum of 10" Hg in the sealing chamber.

Table #1 displays the four setups of various timer settings that were used during the experiments to control the Raque Heat Seal operation.. There are three operations occurring in the sealer: "Evacuation", "Sealing" and "Vacuum Release". Each operation has two timers, a delay timer and a process timer. The delay timer of each operation starts at the same time, eg at closing of the seal chamber. After the delay timer is timed out, the process timer starts. After the process timer for the sealing operation has timed out, the chamber opens. This means that all operations, including the Vacuum release needs to be completed by the end of the sealing operation. The operation of the Raque heat sealer requires that the vacuum is released during the sealing cycle and therefore does not allow the seal to "set" before the vacuum can be released. This will of course increase the capacity of the sealer but might also cause seal wrinkles due to tension in the lid material. It means that the equipment relies on a mechanical seal between the internal and exterior of the container during the sealing process to maintain the residual gas level. While the seal chamber is brought back to atmospheric pressure, the internal container must remain under the "vacuum condition" in order to control the residual gas level inside the container.
The table also estimates the maximum line speed that could be achieved in any of the timer setups. Using setup #3 with the longest vacuum and seal time reduced the maximum line speed to 15 trays/min which was the highest line speed used in these experiments

	Setup #1	Setup #2	Setup #3	Setup #4
Vacuum Delay [sec]	0.1	0.1	0.1	0.1
Vacuum Process [sec]	1.0	0.2	1.0	0.2
Sealing Delay [sec]	1.3	0.5	1.3	0.5
Sealing Process [sec]	2.5	2.5	3.5	3.5
Vent Delay [sec]	1.5	0.7	1.5	0.7
Vent Process [sec]	2.3	2.3	3.3	3.3
Max Cap [Trays/Min]	19	24	15	21

After the sealing process, the trays were inspected for seal defects as identified in MIL-PRF-32004A, (Dated 5-MAR-01). A limited number of trays were evaluated for residual gas content. The data was then analyzed for the response variables residual gas and defective tray. The response variable "defective tray", could either be caused by a critical, major or minor defect, such as open seal (critical) or minor anomaly (minor).

To increase the efficiency of the experiment and cut down on the cost of the raw materials, the sausages were several times reused by draining them from their water and placing them in new trays for the following experiment. Small absorption of water by the sausage was compensated by reducing the water added during the liquid fill operation.

5 Fractional Factorial Experimental Design:

The objective of the experiments was to investigate the effect of the factors on the responses by using two levels (low and high) for every factor. Analysis of the results would reveal the most important factors that can then be investigated in a Phase II experimental study to determine in more detail the interactions between those variables and the optimal values for these factors.

Initially the following variable were selected for this experimental design:

- Product Fill Weight
- Product Temperature
- Line Speed
- Vacuum Time
- Seal Time

After initial test in December 2000, it was determined that the high temperature product samples caused moisture condensation in the seal area which then led to a high percentage of seal anomalies, even though the seals were clean and dry before entering into the sealing section of the Raque Heat Sealer. It was decided to eliminate this variable from the experimental design and concentrate the efforts on the remaining variables.

Factors	**Pork Sausage Levels**		**Response**
Product fill weight, oz	90	98	**R1**: Number of defective trays
Line speed, trays / min	8	15	
Vacuum Time, sec.	0.2	1.0	**R2**: Residual gas
Sealing Time, sec.	2.5	3.5	

The total number of experiments for a full factorial designed study to determine the main effects and interactions for the Pork Sausage would require 16 experiments ($2^4 = 16$). It was decided to utilize a fractional factorial of 1/2 to reduce the number of experiments to 8 experiments to be more efficient with the resources.

The experimental plan and the results of the runs can be found in Appendix I.

6 Data Analysis

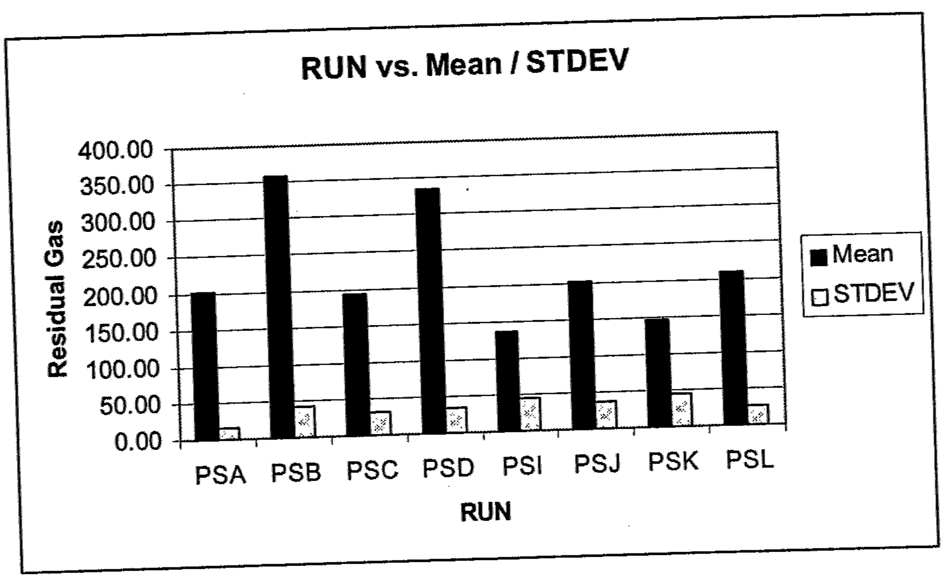
6.1 Residual Gas Data

From each experiment, six trays were selected for residual gas evaluation. The set of six consisted of four consecutive trays, one of each sealing head, and two random selected trays. The Average and Standard Deviation of residual gas for each experiment is reported in the table below

Note: The standard deviation in residual gas was higher than expected and observed in previous experiments. It is expected that the seal chambers leak rate had increased and that a review of the chamber tightness is required.

Means Analysis per Treatment:

RUN	FILL WEIGHT	SPEED	VAC TIME	SEAL TIME	Res Gas Avg	Res Gas Std
PSA	90	8	1	3.5	202.00	16.15
PSB	90	8	0.2	2.5	358.33	40.82
PSC	90	15	1	2.5	193.00	32.64
PSD	90	15	0.2	3.5	334.17	33.23
PSI	98	8	1	2.5	136.00	44.47
PSJ	98	8	0.2	3.5	201.00	36.63
PSK	98	15	1	3.5	147.67	45.56
PSL	98	15	0.2	2.5	209.17	26.72



6.1.1 Residual Gas Data Analysis

6.1.1.1 Summary

The data was first analyzed for pre-retort Residual Gas level by using a multifactor ANOVA analysis. Summary data, obtained from the StatGraphics output can be found in Appendix-II. Based on this data we can conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Fill Weight, and Vacuum Time were all significant at 99% confidence level. Indicating the means for the different Fill Weight, and Vacuum Time were not equal.
- The F-test for Seal Time and Line Speed were not significant at 90% confidence level. Indicating that the means for the different Seal Time and Line Speed were equal.

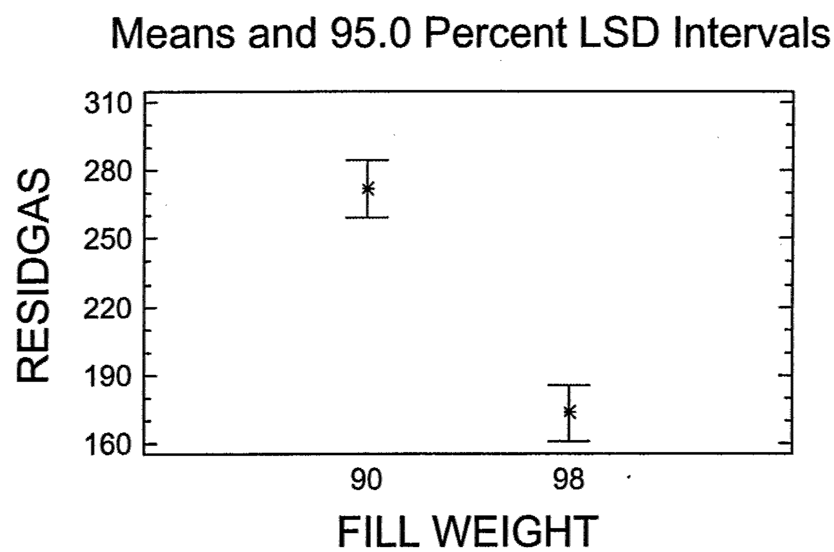
6.1.1.2 Product Fill Weight

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Fill Weight. The test indicated, as expected, that the Fill Weight had a significant impact on the Residual Gas level. Higher fill weight, and consequently less headspace, resulted in a lower Residual Gas level. Fill weight variation will therefore result in a significant variation of residual gas level.

Also, higher fill weights will require less vacuum in order to meet the specified maximum residual gas level.

LSD Grouping	Mean	N	Fill Weight, oz
A	173.5	24	98
B	271.8	24	90

*Means with the same letter are not significantly different.



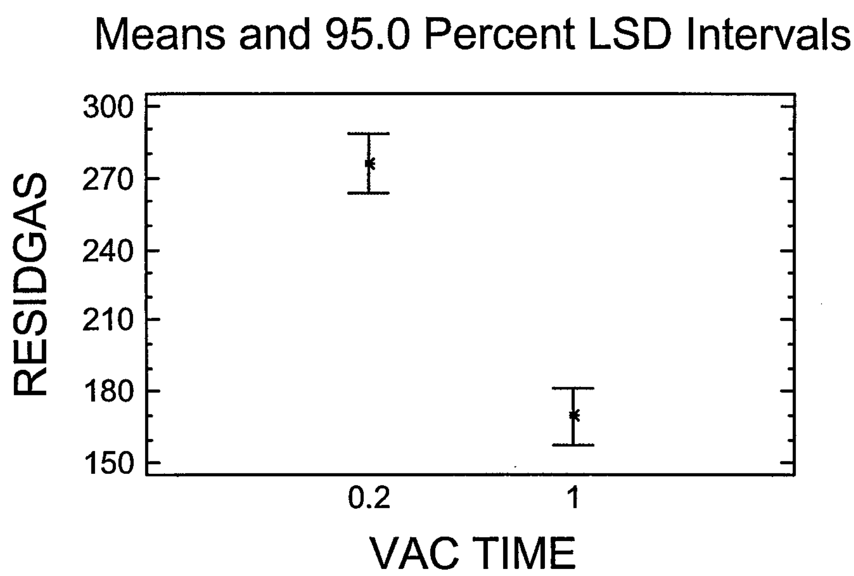
6.1.1.3 Vacuum Time

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Vacuum. The test indicated, as expected, that the residual gas is significantly effected by the vacuum. Stronger Vacuum, and consequently less gas in the headspace, resulted in lower Residual gas level.

As a result, the vacuum timer should be used as the primary control variable to adjust the residual gas level and to compensate for differences in fill weight and product temperature.

LSD Grouping	Mean	N	Vacuum Time, sec.
A	169.6	24	1.0
B	275.6	24	0.2

*Means with the same letter are not significantly different.



6.1.1.4 Line Speed
Multiple comparison test (LSD Test) at 90% confidence level was used to compare between the two levels of Line Speed. The test indicated, as expected, that the residual gas is not significantly effected by the Line Speed.

6.1.1.5 Seal Time
Multiple comparison test (LSD Test) at 90% confidence level was used to compare between the two levels of Seal Time. The test indicated, as expected, that the residual gas is not significantly effected by the Seal Dwell Time.

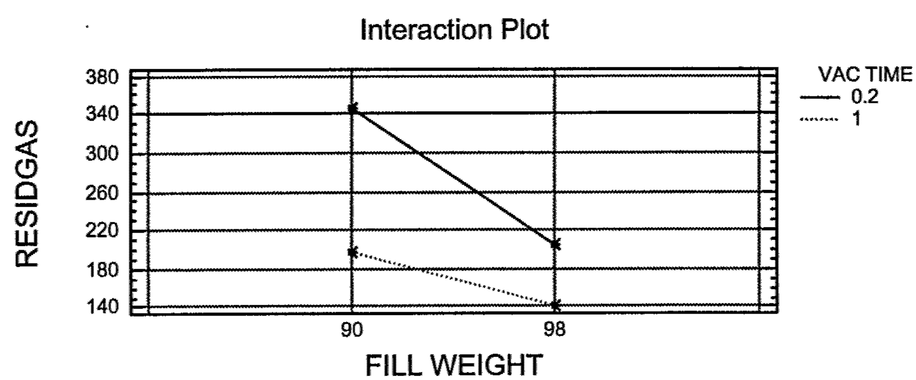
6.1.1.6 Product Temperature
This variable was omitted form the experimental design due to known moisture condensation problems in the seal area. It is unlikely that this product will be filled at elevated temperatures as the pork sausage is refrigerated and the brine most likely is made from "tap" water.

6.1.1.7 Second Order Interactions
Next, an Anova Analysis was done using the three most important factors: Fill Weight, Vacuum and Speed, to estimate the second order interactions between these factors and the response variable "residual gas". The data of this analysis can also be found in Appendix II. The only

second order interaction that was significant was the interaction between Fill Weight and Vacuum Time on Residual Gas. Second Order Interactions between the other factors on Residual Gas were not statistical significant. The second order interaction indicates that the effect of fil weight is greater when the vacuum timer was set to 0.2 seconds

Residual Gas Interaction

FILL WEIGHT [oz[	VAC TIME [sec]	Res Gas Avg [cc]	Res Gas Std [cc]
98	1.0	142	43
98	0.2	205	31
90	1.0	198	25
90	0.2	346	38



6.2 Seal Defects Data:

All the sealed trays were inspected for various defects in the seal area. One or more defects in the seal, either critical, major or minor resulted in a defective tray. The most severe defect was used to log as the reason for the defective tray. The percent defective trays per treatment is reported in the table below

RUN	FILL WEIGHT	SPEED	VAC TIME	SEAL TIME	Total No. of Defect Trays	Total No. of Trays	% Defective
PSA	90	8	1	3.5	3	48	0.06
PSB	90	8	0.2	2.5	11	48	0.23
PSC	90	15	1	2.5	25	48	0.52
PSD	90	15	0.2	3.5	12	48	0.25
PSI	98	8	1	2.5	16	48	0.33
PSJ	98	8	0.2	3.5	3	48	0.06
PSK	98	15	1	3.5	10	48	0.21
PSL	98	15	0.2	2.5	20	48	0.40

6.2.1 Defective Tray Analysis

6.2.1.1 Summary

The data was analyzed by using a multifactor ANOVA analysis. Summary data, obtained from the StatGraphics output can be found in Appendix-III. Based on this data we can conclude that:

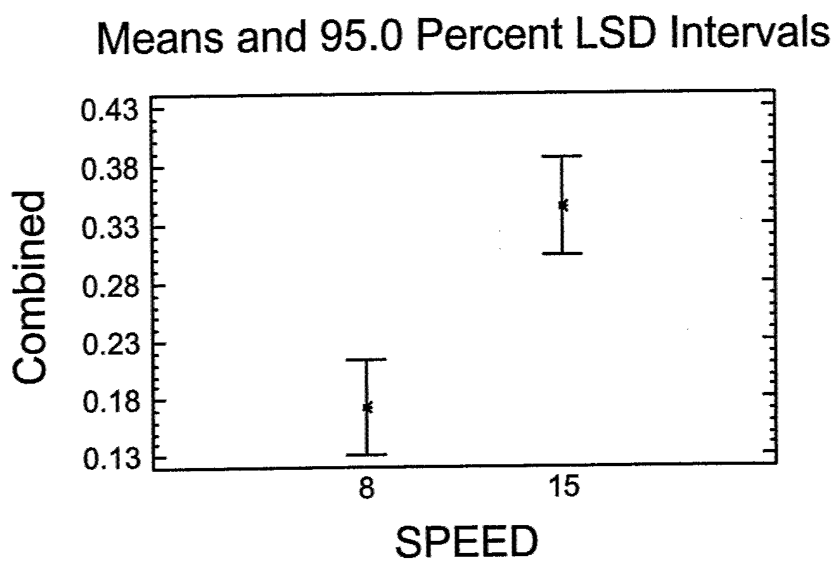
- The F-test for the parameters: Line Speed and Seal Time were significant at 99% confidence level, indicating the means at the different factor levels were not equal.
- The F-test for Fill Weight, and Vacuum Time were not significant at 90% confidence level, indicating the means at the different Fill Weight, and Vacuum Time were not different.

6.2.1.2 Line Speed

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between two different Line Speeds. The output from the test indicated that a lower defect rate can be achieved at the lower Line Speed of 8 trays/min. There are two reasons identified for this behavior. The first reason for this is that the seal area is "contaminated" during the brine fill. A higher line speed requires faster fluid flow, more splashing and thus more contamination. The second reason is attributed to the wiping of the seal area before it enters the sealing chamber. The faster line runs, the less time the wiper has to clean/dry these flanges. High speed manufacturability needs to focus on a liquid delivery system that minimizes the splashing on the seals.

LSD Grouping	Mean	N	Line Speed, trays/min
A	0.34	192	15
B	0.17	192	8

*Means with the same letter are not significantly different.

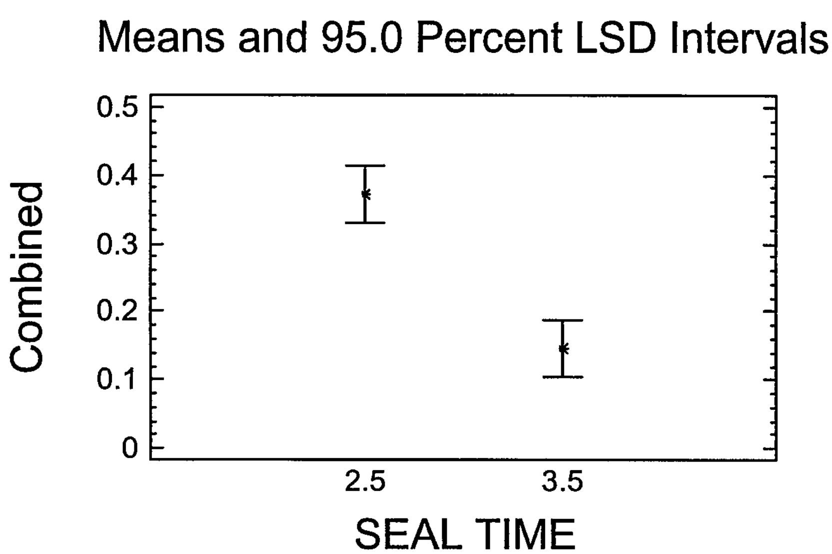


6.2.1.3 Seal Time

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Seal Time.. The output from the test indicated a lower defect rate when the tray was sealed with a 3.5 second dwell time. The longer seal dwell times tend to push out the top layer of molten poly propylene, and in case where there is moisture entrapment, it also tends to push out this moisture. The moisture is burned off and what ever moisture remains tend to form small anomalies that are located in a ridge on the inside of the seal. Anomalies on the inside of the seal were not scored as we do not consider this to be part of the first 1/16" of the seal.

LSD Grouping	Mean	N	Seal Time, sec.
A	0.14	192	3.5
B	0.36	192	2.5

*Means with the same letter are not significantly different.



6.2.1.4 Vacuum Time

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Vacuum Time.. The output from the test indicated that the defect rate was not significantly effected by the vacuum time

6.2.1.5 Product Fill Weight

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Fill Weight.. The output from the test indicated that the defect rate was not significantly effected by the fill weight.

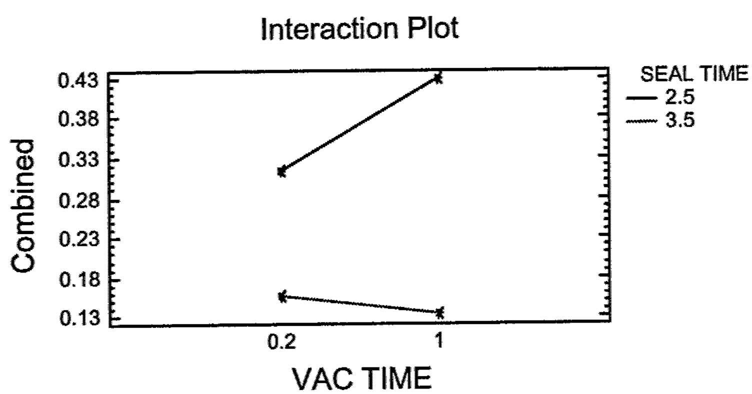
6.2.1.6 Product Temperature

This variable was omitted from the study

6.2.1.7 Second Order Interactions

Next, an Anova Analysis was performed on the data using three factors, line speed, seal time, and vacuum. The only significant second order interaction that was established is the interaction between seal time, vacuum time and defective trays. At shorter seal times (2.5 seconds) the effect of vacuum is much greater than when seal times of 3.5 seconds are used. It is clear that longer seal times are recommended to make the process less sensitive to the vacuum

Vacuum Time	Seal Time	Percent Defective
0.2	3.5	15.6
1.0	3.5	13.5
0.2	2.5	31.3
1.0	2.5	42.7



7 Conclusions:

- Pre retort residual gas is affected by the fill weight and the vacuum applied. It should be noted that the fill temperature would also have had a significant effect. However this variable was omitted from the study due to it's severe negative effect on seal quality
- Seal defects were mainly affected by the line speed and by the seal time. Increased line speed increased the seal defects. This is caused by the higher liquid fill speed and thus more splashing into the seal area, and the in-ability of a seal wiper to keep up with wiping the tray

seal lid dry. Increased seal time did reduce the problems of moisture entrapment of the seal. The moisture is pushed to the outside edges of the seal. In case of the 3.5 sec seal time, most seal defects were minor anomalies located at the inner edge of the seal. Followed by a nice, clean wide seal.

- Of lesser or no effect were fill weight, and vacuum time. It was expected that a higher vacuum and lower fill weight could cause "vacuum wrinkles in the seal area. Some evidence was found to this extend but it could not be proven to be statistical significant. There is however a possibility that these effects are hidden due to the much larger effect of line speed and seal time.
- Even though Product Temperature was omitted from this study, it was concluded in preliminary experiments that the best product temperature is ambient temperature. If the product is too warm, it will create a high humidity headspace that condenses in the seal area. If the product is too cold, the tray might cool down to the point that the ambient air condenses on the seal. In either case, moisture is incorporated in the seal area and anomalies are created.
- The recommended condition for filling and sealing is:
    - Line Speed: 8 trays/min
    - Fill Weight: 90-98 oz, no significant effect
    - Vacuum Time: 0.2 - 1.0 sec, no significant effect
    - Seal Time: 3.5 seconds
    - Product Temperature: ambient temperature. Too hot or too cold will cause condensation problems

8 References:

1. Hicks, C. R., and Turner, Jr., K. V. (1999), Fundamental Concepts in the Design of Experiments, 5th edition. New York: Oxford University Press, Inc.
2. Dean, A. and Voss, D. (1999), Design and Analysis of Experiments, New York: Springer-Verlag, Inc.
3. STATGRAPHICS Plus (2000), A Manugistics Product, Version 5, Manugistics, Inc., Maryland, USA.

9 Attachments:

Appendix I: Experimental Plan and Results for Pork Sausage in Brine
Appendix II: Residual Gas Data Analysis for Pork Sausage in Brine
Appendix III: Seal Defect Analysis for Pork Sausage in Brine

Appendix I

Experimental Plan and Results
for
Pork Sausage in Brine

Production

Sausage Links in Brine

Prior to the production day 500 lbs of sausages will be defrosted. At the day of production 100 trays will be filled with sausages (72 links per tray). On a need basis these trays will be placed on the conveyor belt and fed into the Raque Sealer. Each tray will be filled with the required quantity of brine, evacuated and sealed at the required production speed. Random samples will be taken from the experiment for QC testing (residual gas and net weight). The lid of the remaining containers will be removed by cutting the lid on the inside of the seal area. The sausages will be drained from the brine, removed from the tray and placed into a new tray. A test will be made to establish if and how much the net weight has increased of these already used sausages and an adjustment will be made in the brine filling system in order to target the same net weight. Above process can be repeated till four runs have been made. Product will be discarded at end of the day. If new sausages need to be used to compensate for losses during the previous experiment, the tray will be filled with a small amount of water equivalent to the water that was absorbed (if any) by the already used sausages. The produced containers will be cleaned and inspected for seal defects at a later date.

Experimental Code	Product Fill Weight	Product Temperature	Line Speed	Vacuum time	Sealing Time
PSA	90 oz	50-70 F	8	1.0	3.5
PSB	90 oz	50-70 F	8	0.2	2.5
PSC	90 oz	50-70 F	15	1.0	2.5
PSD	90 oz	50-70 F	15	0.2	3.5
PSI	98 oz	50-70 F	8	1.0	2.5
PSJ	98 oz	50-70 F	8	0.2	3.5
PSK	98 oz	50-70 F	15	1.0	3.5
PSL	98 oz	50-70 F	15	0.2	2.5

Test ID		PSA-5	PSB-5	PSC-5	PSD-5	
Line Speed		8	8	15	15	
Seal Temp		412	412	412	412	
Seal Pressure		80	80	80	80	
Seal Time		3.5	2.5	2.5	3.5	
Vacuum Time		1.0	0.2	1.0	0.2	
Vacuum Press		18	10	10	18	
Oden Speed		25	25	30	30	
Oden Volume		2655	2505	2505	2455	
Brine Temp		60	60	60	60	
Avg Prod Temp						
Fill Weight avg		2553	2557	2554	2582	
Fill Weight std		6	28	17	34	
Peel Strenght				151/15	146/22	
Residual Gas		202/16	358/41	193/33	334/33	
Trays produced		48	48	48	48	
Open Seals						
Seal Wrinkles						
Abrasion						
Delamination CR						
Delamination MA						
Delamination MI						
Anomalies CR				6	3	
Anomalies MI		3	11	19	9	
Narrow Seals						
Trays Accepted		45	37	23	36	

Test ID		PSI-5	PSJ-5	PSK-5	PSL-5	
Line Speed		8	8	15	15	
Seal Temp		412	412	412	412	
Seal Pressure		80	80	80	80	
Seal Time		2.5	3.5	3.5	2.5	
Vacuum Time		1.0	0.2	1.0	0.2	
Vacuum Press		18	10	18	10	
Oden Speed		20	20	30	30	
Oden Volume		3136	3026	3026	3026	
Brine Temp		60	60	60	60	
Avg Prod Temp						
Fill Weight avg		2770	2775	2731	2772	
Fill Weight std		52	14	26	8	
Seal Strength		145/17				
Res. Gas x/s		136/44	201/37	148/46	209/27	
Trays produced		48	48	48	48	
Open Seals CR						
Seal Wrinkles CR						
Abrasion CR						
Delamination CR						
Delamination MA						
Delamination MI						
Anomalies CR		6		3	4	
Anomalies MI		7	3	7	15	
Narrow Seals MA					1	
Trays Accepted		32	45	38	28	

Appendix II

Residual Gas Data Analysis
for
Pork Sausage in Brine

Residual Gas Data:

RUN	FILL WEIGHT	SPEED	VAC TIME	SEAL TIME	RESIDGAS
PSA	90	8	1	3.5	208
PSA	90	8	1	3.5	184
PSA	90	8	1	3.5	214
PSA	90	8	1	3.5	182
PSA	90	8	1	3.5	202
PSA	90	8	1	3.5	222
PSB	90	8	0.2	2.5	410
PSB	90	8	0.2	2.5	350
PSB	90	8	0.2	2.5	305
PSB	90	8	0.2	2.5	320
PSB	90	8	0.2	2.5	390
PSB	90	8	0.2	2.5	375
PSC	90	15	1	2.5	194
PSC	90	15	1	2.5	170
PSC	90	15	1	2.5	222
PSC	90	15	1	2.5	150
PSC	90	15	1	2.5	184
PSC	90	15	1	2.5	238
PSD	90	15	0.2	3.5	370
PSD	90	15	0.2	3.5	350
PSD	90	15	0.2	3.5	360
PSD	90	15	0.2	3.5	315
PSD	90	15	0.2	3.5	280
PSD	90	15	0.2	3.5	330
PSI	98	8	1	2.5	194
PSI	98	8	1	2.5	74
PSI	98	8	1	2.5	134
PSI	98	8	1	2.5	114
PSI	98	8	1	2.5	180
PSI	98	8	1	2.5	120
PSJ	98	8	0.2	3.5	222
PSJ	98	8	0.2	3.5	224
PSJ	98	8	0.2	3.5	194
PSJ	98	8	0.2	3.5	184
PSJ	98	8	0.2	3.5	242
PSJ	98	8	0.2	3.5	140
PSK	98	15	1	3.5	230
PSK	98	15	1	3.5	116
PSK	98	15	1	3.5	130
PSK	98	15	1	3.5	124
PSK	98	15	1	3.5	172
PSK	98	15	1	3.5	114
PSL	98	15	0.2	2.5	175
PSL	98	15	0.2	2.5	240
PSL	98	15	0.2	2.5	185
PSL	98	15	0.2	2.5	220
PSL	98	15	0.2	2.5	200
PSL	98	15	0.2	2.5	235

Subset Analysis

Analysis Summary

Data variable: RESIDGAS
Code variable: RUN

Number of observations: 48
Number of levels: 8

The StatAdvisor

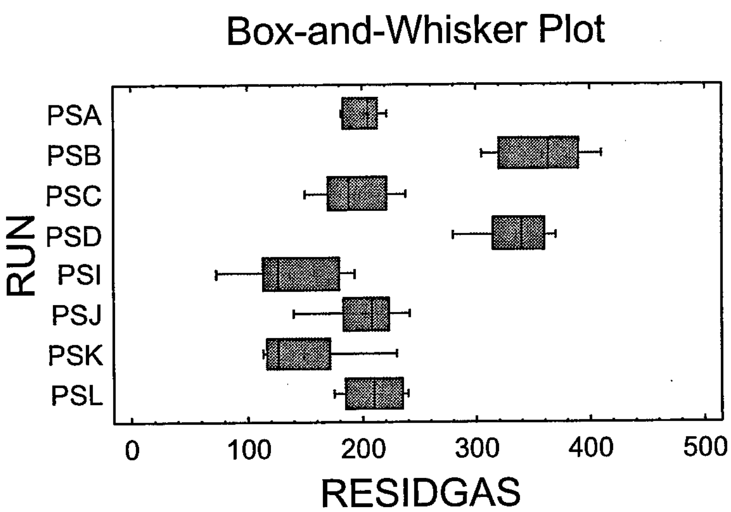
This procedure calculates summary statistics for the values of RESIDGAS corresponding to each of the 8 levels of RUN. It also creates a variety of plots and allows you to save the calculated statistics. Further analyses can be performed on the data using the Oneway Analysis of Variance procedure under Compare on the main menu.

Summary Statistics

Code	Count	Average	Median	Standard Deviation	Minimum	Maximum
PSA	6	202.0	205.0	16.1493	182.0	222.0
PSB	6	358.333	362.5	40.8248	305.0	410.0
PSC	6	193.0	189.0	32.6374	150.0	238.0
PSD	6	334.167	340.0	33.229	280.0	370.0
PSI	6	136.0	127.0	44.4702	74.0	194.0
PSJ	6	201.0	208.0	36.6333	140.0	242.0
PSK	6	147.667	127.0	45.5617	114.0	230.0
PSL	6	209.167	210.0	26.7239	175.0	240.0
Total	48	222.667	205.0	83.3639	74.0	410.0

The StatAdvisor

This table shows sample statistics for the 8 levels of RUN.



Means Table with Standard Error Intervals

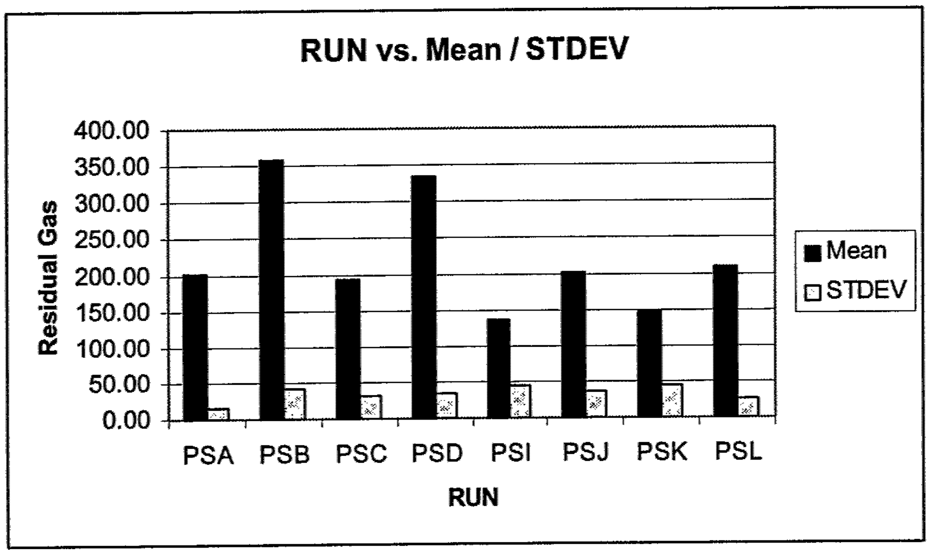
Code	Count	Mean	Standard Error	Lower Limit	Upper Limit
PSA	6	202.0	6.59293	195.407	208.593
PSB	6	358.333	16.6667	341.667	375.0
PSC	6	193.0	13.3242	179.676	206.324
PSD	6	334.167	13.5657	320.601	347.732
PSI	6	136.0	18.1549	117.845	154.155
PSJ	6	201.0	14.9555	186.045	215.955
PSK	6	147.667	18.6005	129.066	166.267
PSL	6	209.167	10.91	198.257	220.077
Total	48	222.667	12.0325	210.634	234.699

The StatAdvisor

This table shows the sample means and standard errors for the 8 levels of RUN. Also shown are intervals representing the means plus and minus one standard error.

Means Analysis per Treatment:

RUN	FILL WEIGHT	SPEED	VAC TIME	SEAL TIME	RESIDGAS	Mean	STDEV
PSA	90	8	1	3.5	208	202.00	16.15
PSB	90	8	0.2	2.5	410	358.33	40.82
PSC	90	15	1	2.5	194	193.00	32.64
PSD	90	15	0.2	3.5	370	334.17	33.23
PSI	98	8	1	2.5	194	136.00	44.47
PSJ	98	8	0.2	3.5	222	201.00	36.63
PSK	98	15	1	3.5	230	147.67	45.56
PSL	98	15	0.2	2.5	175	209.17	26.72



Multiple Regression Analysis

Dependent variable: RESIDGAS

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1472.79	148.265	9.93352	0.0000
FILL WEIGHT	-12.3021	1.51033	-8.14528	0.0000
SPEED	-0.47619	1.72609	-0.275877	0.7840
VAC TIME	-132.5	15.1033	-8.7729	0.0000
SEAL TIME	-2.91667	12.0827	-0.241393	0.8104

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	251298.0	4	62824.4	35.86	0.0000
Residual	75331.2	43	1751.89		
Total (Corr.)	326629.0	47			

R-squared = 76.9368 percent
R-squared (adjusted for d.f.) = 74.7913 percent
Standard Error of Est. = 41.8556
Mean absolute error = 30.1389
Durbin-Watson statistic = 2.14131 (P=0.1470)
Lag 1 residual autocorrelation = -0.0719767

The StatAdvisor

The output shows the results of fitting a multiple linear regression model to describe the relationship between RESIDGAS and 4 independent variables. The equation of the fitted model is

RESIDGAS = 1472.79 - 12.3021*FILL WEIGHT - 0.47619*SPEED - 132.5*VAC TIME - 2.91667*SEAL TIME

Since the P-value in the ANOVA table is less than 0.01, there is a statistically significant relationship between the variables at the 99% confidence level.

The R-Squared statistic indicates that the model as fitted explains 76.9368% of the variability in RESIDGAS. The adjusted R-squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 74.7913%. The standard error of the estimate shows the standard deviation of the residuals to be 41.8556. This value can be used to construct prediction limits for new observations by selecting the Reports option from the text menu. The mean absolute error (MAE) of 30.1389 is the average value of the residuals. The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in your data file. Since the P-value is greater than 0.05, there is no indication of serial autocorrelation in the residuals.

In determining whether the model can be simplified, notice that the highest P-value on the independent variables is 0.8104, belonging to SEAL TIME. Since the P-value is greater or equal to 0.10, that term is not statistically significant at the 90% or higher confidence level. Consequently, you should consider removing SEAL TIME from the model.

Multifactor ANOVA - RESIDGAS

Analysis Summary

Dependent variable: RESIDGAS
Factors:
- FILL WEIGHT
- SEAL TIME
- SPEED
- VAC TIME

Number of complete cases: 48

The StatAdvisor

This procedure performs a multifactor analysis of variance for RESIDGAS. It constructs various tests and graphs to determine which factors have a statistically significant effect on RESIDGAS. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.

Analysis of Variance for RESIDGAS - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:FILL WEIGHT	116230.0	1	116230.0	66.35	0.0000
B:SEAL TIME	102.083	1	102.083	0.06	0.8104
C:SPEED	133.333	1	133.333	0.08	0.7840
D:VAC TIME	134832.0	1	134832.0	76.96	0.0000
RESIDUAL	75331.2	43	1751.89		
TOTAL (CORRECTED)	326629.0	47			

All F-ratios are based on the residual mean square error.

The StatAdvisor

The ANOVA table decomposes the variability of RESIDGAS into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 2 P-values are less than 0.05, these factors have a statistically significant effect on RESIDGAS at the 95.0% confidence level.

Table of Least Squares Means for RESIDGAS
with 95.0 Percent Confidence Intervals

Level	Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN	48	222.667			

FILL WEIGHT					
90	24	271.875	8.54373	254.645	289.105
98	24	173.458	8.54373	156.228	190.688
SEAL TIME					
2.5	24	224.125	8.54373	206.895	241.355
3.5	24	221.208	8.54373	203.978	238.438
SPEED					
8	24	224.333	8.54373	207.103	241.563
15	24	221.0	8.54373	203.77	238.23
VAC TIME					
0.2	24	275.667	8.54373	258.437	292.897
1	24	169.667	8.54373	152.437	186.897

The StatAdvisor

This table shows the mean RESIDGAS for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.

Multiple Range Tests for RESIDGAS by FILL WEIGHT

Method: 95.0 percent LSD

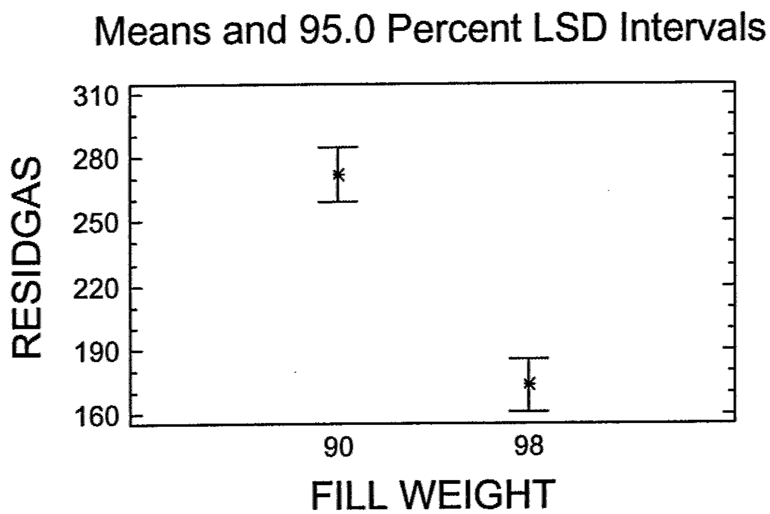
FILL WEIGHT	Count	LS Mean	LS Sigma	Homogeneous Groups
98	24	173.458	8.54373	X
90	24	271.875	8.54373	X

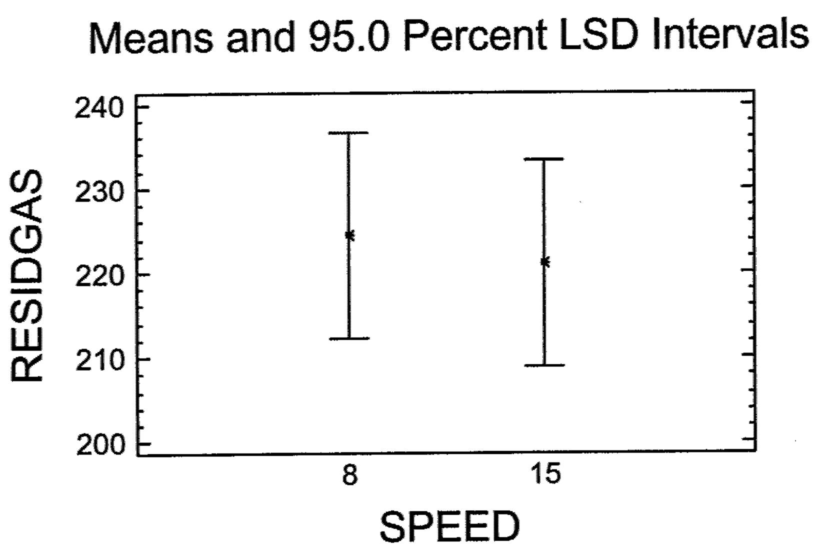
Contrast	Difference	+/- Limits
90 - 98	*98.4167	24.3671

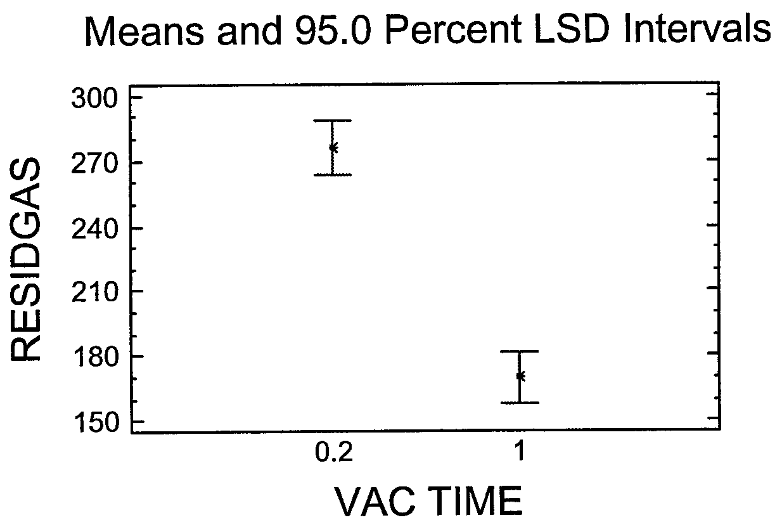
* denotes a statistically significant difference.

The StatAdvisor

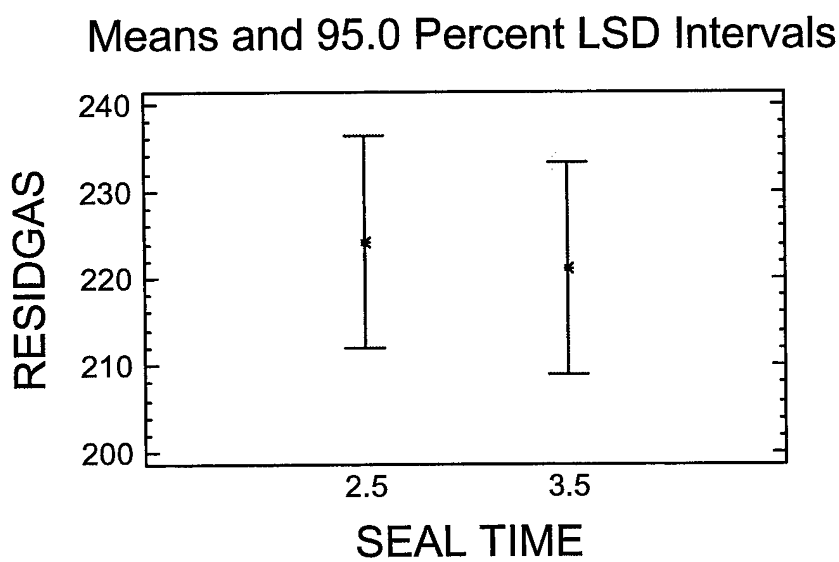
This table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. An asterisk has been placed next to 1 pair, indicating that this pair shows a statistically significant difference at the 95.0% confidence level. At the top of the page, 2 homogenous groups are identified using columns of X's. Within each column, the levels containing X's form a group of means within which there are no statistically significant differences. The method currently being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0.


Means and 95.0 Percent LSD Intervals
RESIDGAS
310
280
250
220
190
160
90
98
FILL WEIGHT


Means and 95.0 Percent LSD Intervals
RESIDGAS
240
230
220
210
200
8
15
SPEED



Means and 95.0 Percent LSD Intervals
RESIDGAS
300
270
240
210
180
150
0.2
1
VAC TIME



Means and 95.0 Percent LSD Intervals
RESIDGAS
240
230
220
210
200
2.5
3.5
SEAL TIME

Multifactor ANOVA - RESIDGAS

Analysis Summary

Dependent variable: RESIDGAS
Factors:
SPEED
FILL WEIGHT
VAC TIME

Number of complete cases: 48

The StatAdvisor

This procedure performs a multifactor analysis of variance for RESIDGAS. It constructs various tests and graphs to determine which factors have a statistically significant effect on RESIDGAS. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.

Analysis of Variance for RESIDGAS - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:SPEED	133.333	1	133.333	0.11	0.7454
B:FILL WEIGHT	116230.0	1	116230.0	93.19	0.0000
C:VAC TIME	134832.0	1	134832.0	108.11	0.0000
INTERACTIONS					
AB	2106.75	1	2106.75	1.69	0.2010
AC	261.333	1	261.333	0.21	0.6495
BC	21930.7	1	21930.7	17.58	0.0001
RESIDUAL	51134.4	41	1247.18		
TOTAL (CORRECTED)	326629.0	47			

All F-ratios are based on the residual mean square error.

The StatAdvisor

The ANOVA table decomposes the variability of RESIDGAS into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 3 P-values are less than 0.05, these factors have a statistically significant effect on RESIDGAS at the 95.0% confidence level.

Table of Least Squares Means for RESIDGAS
with 95.0 Percent Confidence Intervals

	Stnd.	Lower	Upper

Level		Count	Mean	Error	Limit	Limit
GRAND MEAN		48	222.667			
SPEED						
8		24	224.333	7.20874	209.775	238.892
15		24	221.0	7.20874	206.442	235.558
FILL WEIGHT						
90		24	271.875	7.20874	257.317	286.433
98		24	173.458	7.20874	158.9	188.017
VAC TIME						
0.2		24	275.667	7.20874	261.108	290.225
1		24	169.667	7.20874	155.108	184.225
SPEED by FILL WEIGHT						
8	90	12	280.167	10.1947	259.578	300.755
8	98	12	168.5	10.1947	147.911	189.089
15	90	12	263.583	10.1947	242.995	284.172
15	98	12	178.417	10.1947	157.828	199.005
SPEED by VAC TIME						
8	0.2	12	279.667	10.1947	259.078	300.255
8	1	12	169.0	10.1947	148.411	189.589
15	0.2	12	271.667	10.1947	251.078	292.255
15	1	12	170.333	10.1947	149.745	190.922
FILL WEIGHT by VAC TIME						
90	0.2	12	346.25	10.1947	325.661	366.839
90	1	12	197.5	10.1947	176.911	218.089
98	0.2	12	205.083	10.1947	184.495	225.672
98	1	12	141.833	10.1947	121.245	162.422

The StatAdvisor

This table shows the mean RESIDGAS for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.

Multiple Range Tests for RESIDGAS by SPEED

Method: 95.0 percent LSD

SPEED	Count	LS Mean	LS Sigma	Homogeneous Groups
15	24	221.0	7.20874	X
8	24	224.333	7.20874	X

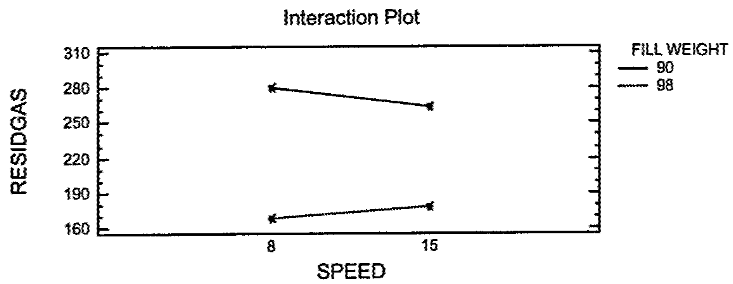
Contrast	Difference	+/- Limits
8 - 15	3.33333	20.5886

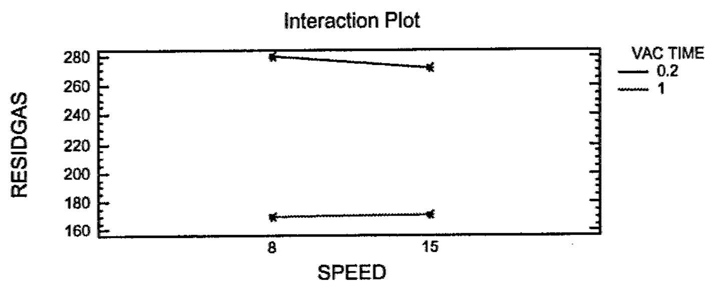
* denotes a statistically significant difference.

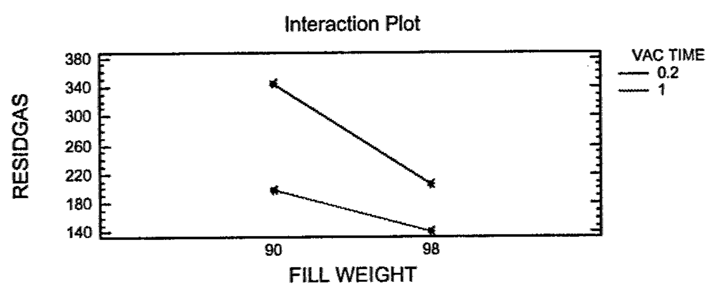
The StatAdvisor

This table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. There are no statistically significant differences between any pair of means at the 95.0% confidence level. At the top of the page, one homogenous group is identified by a column of X's. Within each column, the levels containing X's form a group of means within which there are no statistically significant differences. The method currently being used to discriminate among the means is Fisher's least

significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0.







Appendix III

Seal Defect Analysis
for
Pork Sausage in Brine

Defective Tray Data:

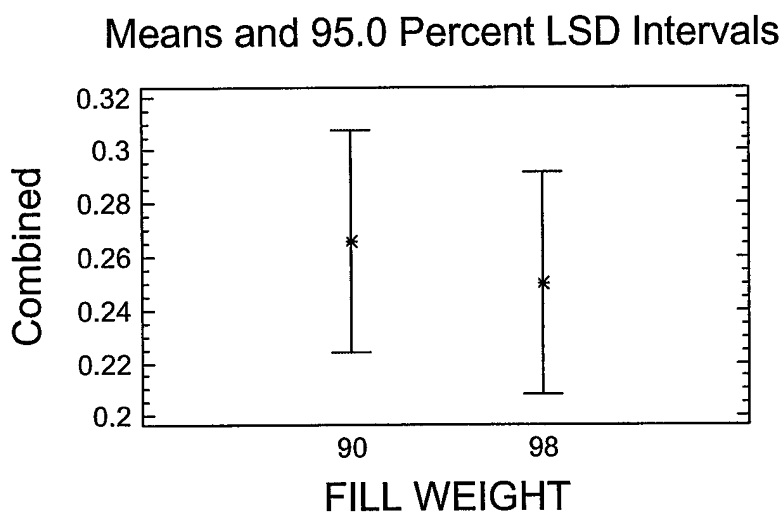
RUN	FILL WEIGHT	SPEED	VAC TIME	SEAL TIME	RESIDGAS	Total No. of Defect Trays	Total No. of Trays	Mean
PSA	90	8	1	3.5	208	3	48	0.06
PSB	90	8	0.2	2.5	410	11	48	0.23
PSC	90	15	1	2.5	194	25	48	0.52
PSD	90	15	0.2	3.5	370	12	48	0.25
PSI	98	8	1	2.5	194	16	48	0.33
PSJ	98	8	0.2	3.5	222	3	48	0.06
PSK	98	15	1	3.5	230	10	48	0.21
PSL	98	15	0.2	2.5	175	20	48	0.40

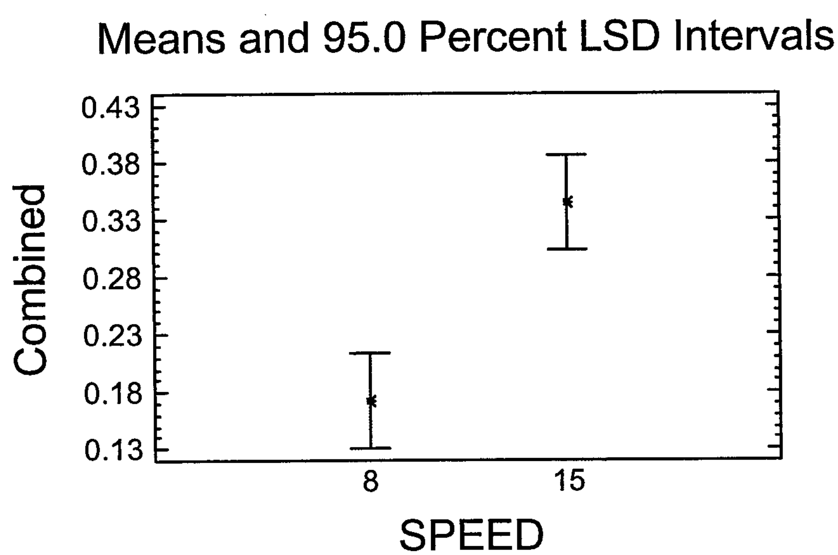
Multifactor ANOVA - No. of Defect. Trays

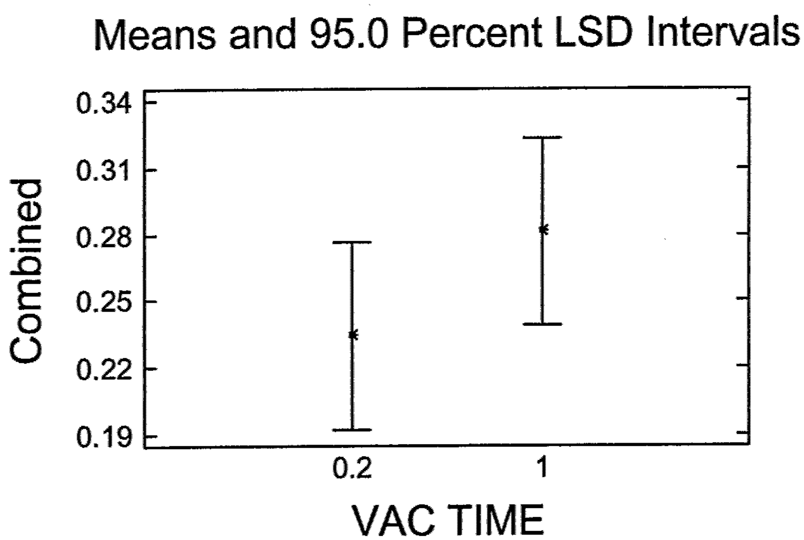
```
Analysis Summary

Dependent variable: Combined
Factors:
        FILL WEIGHT
        SPEED
        VAC TIME
        SEAL TIME

Number of complete cases: 384
```

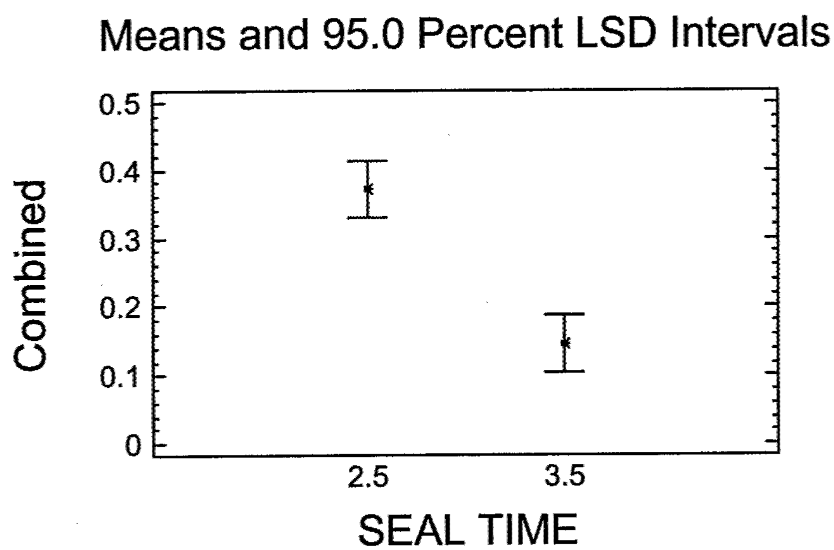
Analysis of Variance - Type III Sums of Squares

```
--------------------------------------------------------------------------------
Source                  Sum of Squares     Df    Mean Square    F-Ratio    P-Value
--------------------------------------------------------------------------------
MAIN EFFECTS
 A:FILL WEIGHT               0.0234375      1      0.0234375       0.14     0.7131
 B:SPEED                       2.83594      1        2.83594      16.39     0.0001
 C:VAC TIME                   0.210938      1       0.210938       1.22     0.2703
 D:SEAL TIME                    4.8151      1         4.8151      27.82     0.0000

RESIDUAL                       65.5911    379       0.173064
--------------------------------------------------------------------------------
TOTAL (CORRECTED)              73.4766    383
--------------------------------------------------------------------------------
All F-ratios are based on the residual mean square error.
```


Means and 95.0 Percent LSD Intervals
0.32
0.3
0.28
0.26
0.24
0.22
0.2
Combined
90
98
FILL WEIGHT


Means and 95.0 Percent LSD Intervals
0.43
0.38
0.33
0.28
0.23
0.18
0.13
Combined
8
15
SPEED


Means and 95.0 Percent LSD Intervals
Combined
0.34
0.31
0.28
0.25
0.22
0.19
0.2
1
VAC TIME


Means and 95.0 Percent LSD Intervals
Combined
0.5
0.4
0.3
0.2
0.1
0
2.5
3.5
SEAL TIME

Multifactor ANOVA - Combined

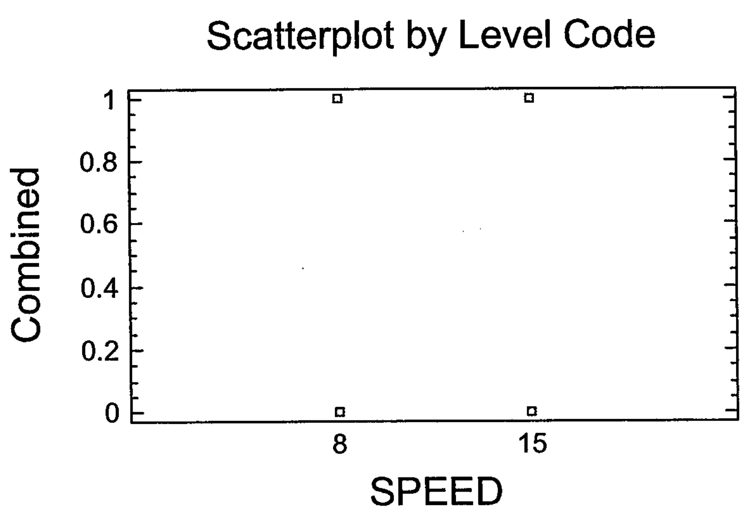
Analysis Summary

Dependent variable: Combined
Factors:
SPEED
VAC TIME
SEAL TIME

Number of complete cases: 384

The StatAdvisor

This procedure performs a multifactor analysis of variance for Combined. It constructs various tests and graphs to determine which factors have a statistically significant effect on Combined. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.



Analysis of Variance for Combined - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:SPEED	2.83594	1	2.83594	16.41	0.0001
B:VAC TIME	0.210938	1	0.210938	1.22	0.2700
C:SEAL TIME	4.8151	1	4.8151	27.86	0.0000
INTERACTIONS					
AB	0.00260417	1	0.00260417	0.02	0.9024
AC	0.00260417	1	0.00260417	0.02	0.9024
BC	0.440104	1	0.440104	2.55	0.1114
RESIDUAL	65.1693	377	0.172863		

TOTAL (CORRECTED)	73.4766	383

All F-ratios are based on the residual mean square error.

The StatAdvisor

The ANOVA table decomposes the variability of Combined into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 2 P-values are less than 0.05, these factors have a statistically significant effect on Combined at the 95.0% confidence level.

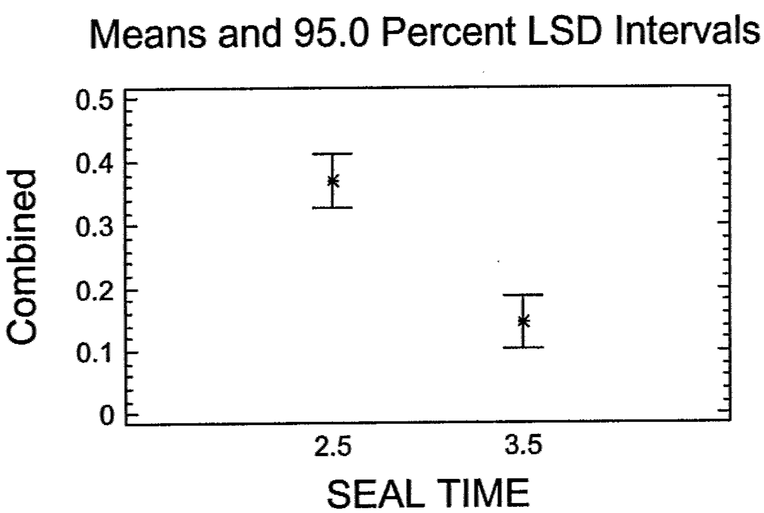


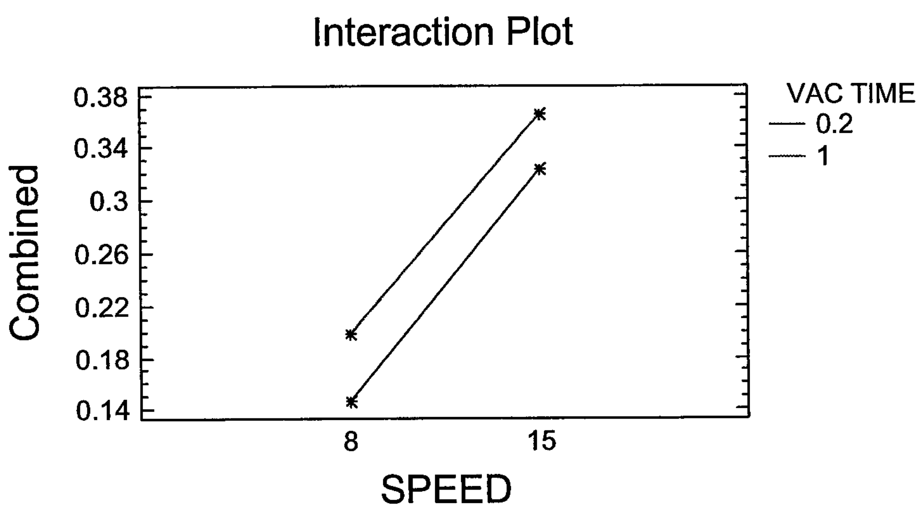
Table of Least Squares Means for Combined
with 95.0 Percent Confidence Intervals

Level		Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN		384	0.257813			
SPEED						
8		192	0.171875	0.0300054	0.112876	0.230874
15		192	0.34375	0.0300054	0.284751	0.402749
VAC TIME						
0.2		192	0.234375	0.0300054	0.175376	0.293374
1		192	0.28125	0.0300054	0.222251	0.340249
SEAL TIME						
2.5		192	0.369792	0.0300054	0.310793	0.428791
3.5		192	0.145833	0.0300054	0.0868342	0.204832
SPEED by VAC TIME						
8	0.2	96	0.145833	0.0424341	0.062396	0.229271
8	1	96	0.197917	0.0424341	0.114479	0.281354
15	0.2	96	0.322917	0.0424341	0.239479	0.406354
15	1	96	0.364583	0.0424341	0.281146	0.448021
SPEED by SEAL TIME						
8	2.5	96	0.28125	0.0424341	0.197813	0.364687
8	3.5	96	0.0625	0.0424341	-0.0209374	0.145937
15	2.5	96	0.458333	0.0424341	0.374896	0.541771
15	3.5	96	0.229167	0.0424341	0.145729	0.312604
VAC TIME by SEAL TIME						

0.2	2.5	96	0.3125	0.0424341	0.229063	0.395937
0.2	3.5	96	0.15625	0.0424341	0.0728126	0.239687
1	2.5	96	0.427083	0.0424341	0.343646	0.510521
1	3.5	96	0.135417	0.0424341	0.0519793	0.218854

The StatAdvisor

This table shows the mean Combined for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.



Multiple Range Tests for Combined by SEAL TIME

Method: 95.0 percent LSD

SEAL TIME	Count	LS Mean	LS Sigma	Homogeneous Groups
3.5	192	0.145833	0.0300054	X
2.5	192	0.369792	0.0300054	X

Contrast	Difference	+/- Limits
2.5 - 3.5	*0.223958	0.0834374

* denotes a statistically significant difference.

The StatAdvisor

This table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. An asterisk has been placed next to 1 pair, indicating that this pair shows a statistically significant difference at the 95.0% confidence level. At the top of the page, 2 homogenous groups are identified using columns of X's. Within each column, the levels containing X's form a group of means within which there are no

statistically significant differences. The method currently being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0.

Multifactor ANOVA - Combined

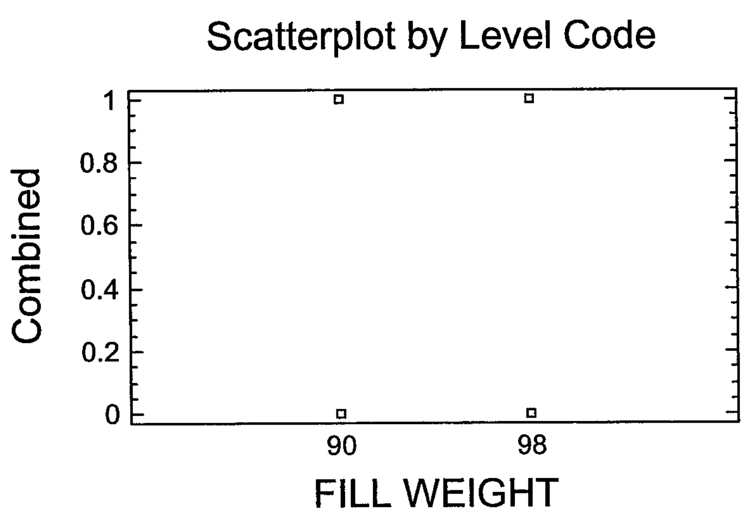
Analysis Summary

Dependent variable: Combined
Factors:
FILL WEIGHT
VAC TIME
SEAL TIME

Number of complete cases: 384

The StatAdvisor

This procedure performs a multifactor analysis of variance for Combined. It constructs various tests and graphs to determine which factors have a statistically significant effect on Combined. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.



Analysis of Variance for Combined - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:FILL WEIGHT	0.0234375	1	0.0234375	0.13	0.7187
B:VAC TIME	0.210938	1	0.210938	1.17	0.2801
C:SEAL TIME	4.8151	1	4.8151	26.70	0.0000
INTERACTIONS					
AB	0.00260417	1	0.00260417	0.01	0.9044
AC	0.00260417	1	0.00260417	0.01	0.9044
BC	0.440104	1	0.440104	2.44	0.1191
RESIDUAL	67.9818	377	0.180323		

```
TOTAL (CORRECTED)              73.4766     383
--------------------------------------------------------------------------------
All F-ratios are based on the residual mean square error.
```

The StatAdvisor

The ANOVA table decomposes the variability of Combined into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since one P-value is less than 0.05, this factor has a statistically significant effect on Combined at the 95.0% confidence level.

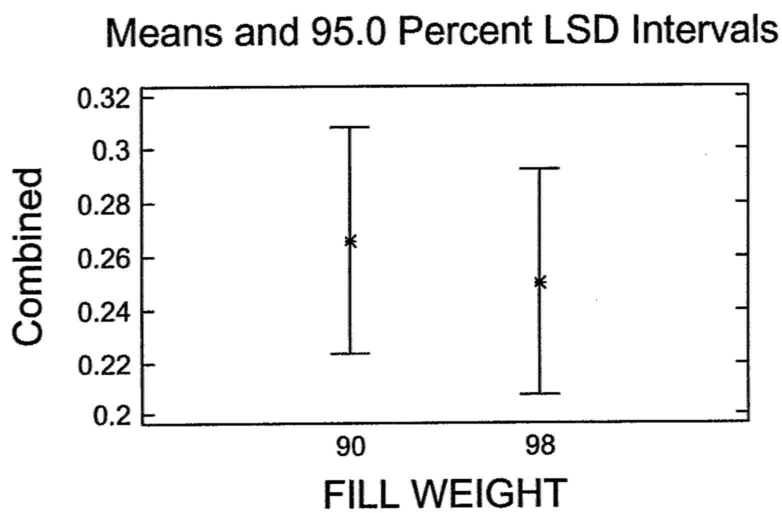


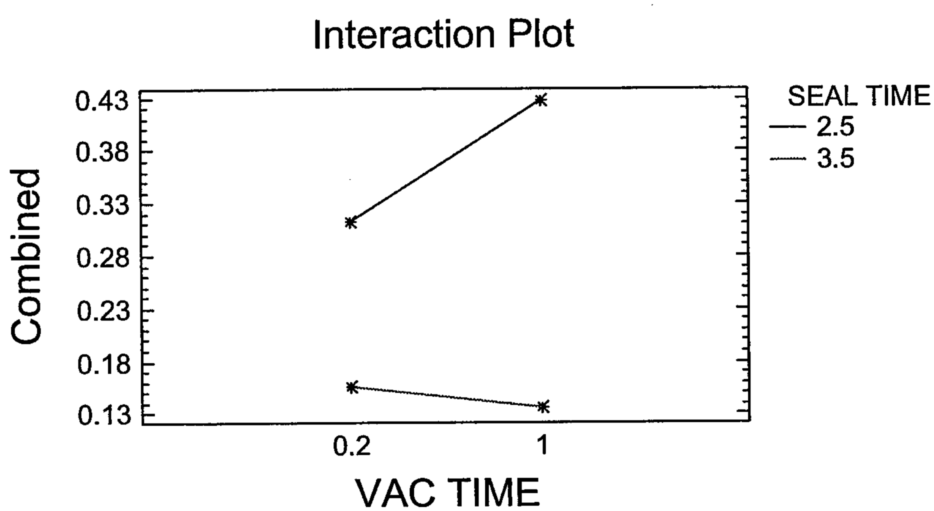
Table of Least Squares Means for Combined
with 95.0 Percent Confidence Intervals

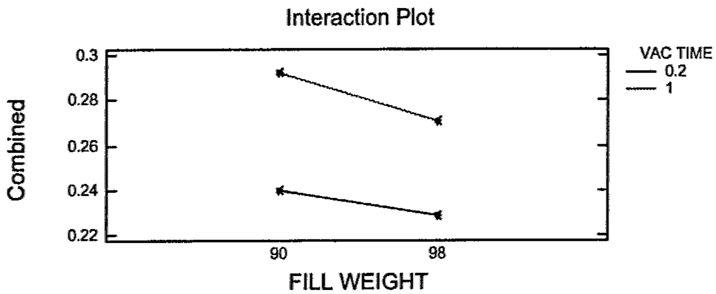
Level		Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN		384	0.257813			
FILL WEIGHT						
90		192	0.265625	0.0306461	0.205366	0.325884
98		192	0.25	0.0306461	0.189741	0.310259
VAC TIME						
0.2		192	0.234375	0.0306461	0.174116	0.294634
1		192	0.28125	0.0306461	0.220991	0.341509
SEAL TIME						
2.5		192	0.369792	0.0306461	0.309533	0.43005
3.5		192	0.145833	0.0306461	0.0855746	0.206092
FILL WEIGHT by VAC TIME						
90	0.2	96	0.239583	0.0433401	0.154365	0.324802
90	1	96	0.291667	0.0433401	0.206448	0.376885
98	0.2	96	0.229167	0.0433401	0.143948	0.314385
98	1	96	0.270833	0.0433401	0.185615	0.356052
FILL WEIGHT by SEAL TIME						
90	2.5	96	0.375	0.0433401	0.289781	0.460219
90	3.5	96	0.15625	0.0433401	0.0710312	0.241469
98	2.5	96	0.364583	0.0433401	0.279365	0.449802
98	3.5	96	0.135417	0.0433401	0.0501979	0.220635
VAC TIME by SEAL TIME						
0.2	2.5	96	0.3125	0.0433401	0.227281	0.397719

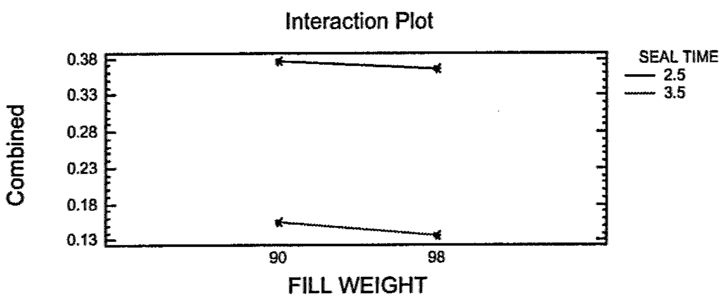
0.2	3.5	96	0.15625	0.0433401	0.0710312	0.241469
1	2.5	96	0.427083	0.0433401	0.341865	0.512302
1	3.5	96	0.135417	0.0433401	0.0501979	0.220635

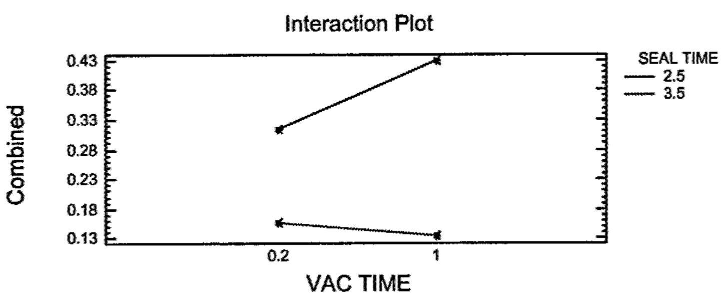
The StatAdvisor

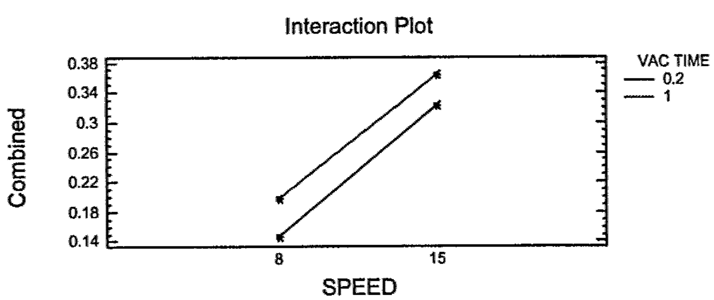
This table shows the mean Combined for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.

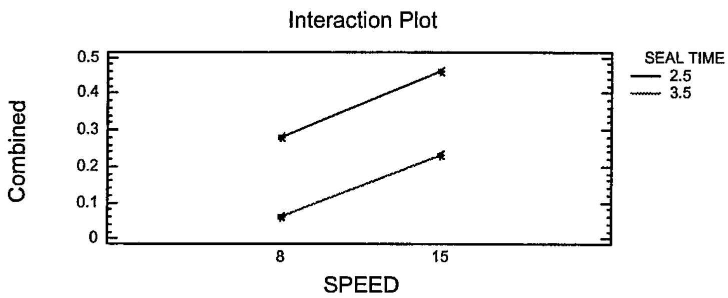



Interaction Plot
Combined
0.3
0.28
0.26
0.24
0.22
90
98
FILL WEIGHT
VAC TIME
0.2
1


Interaction Plot
Combined
0.38
0.33
0.28
0.23
0.18
0.13
90
98
FILL WEIGHT
SEAL TIME
2.5
3.5


Interaction Plot
Combined
0.43
0.38
0.33
0.28
0.23
0.18
0.13
0.2
1
VAC TIME
SEAL TIME
2.5
3.5


Interaction Plot
Combined
0.38
0.34
0.3
0.26
0.22
0.18
0.14
8
15
SPEED
VAC TIME
0.2
1



Interaction Plot
Combined
0.5
0.4
0.3
0.2
0.1
0
8
15
SPEED
SEAL TIME
2.5
3.5

COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Filling & Sealing Studies of

Creamed Ground Beef in Polymeric Tray

Technical Working Paper (TWP-218)

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1. Introduction

Since the inception of the Tray Pack Ration, the product has been packaged in a heavy metal tray shaped can with a double seamed metal lid and processed in non rotary, batch retort systems. Due to the declining supplier base for the metal tray can and lid and various problems with the interior coating of the cans, an alternative package was developed utilizing a polymeric tray body with a laminated foil and polymer lidstock. The change over to this particular container has a significant impact on the Manufacturability of the product. Double rolled seams are replaced by fusion seals and contamination of seal area are more likely to result in seal defects. On the other hand, it is expected that the over all through put rate of a heat sealer can exceed that of a can seamer for the half steam table tray.

The sensitivity of seal contamination to seal defects, requires a thorough understanding of the interactions of process, product and packaging variables. This study documents these interactions and gives guidance to the producers in selecting process, product and packaging parameters that optimize the yield of the process and therefore minimize the cost of the product. This study attempts to also high light via the same interactions the specification limits that might affect the manufacturability of the product.

2. Objective:

Investigate the effect of selected product, process and packaging parameters in a filling and sealing process on the quality of the seal using "Creamed Ground Beef".

3. Product and Package Description:

Creamed Ground Beef used in this study, complies with the Contract Technical Requirement dated January 11, 2000.

The precooked ground beef used for this study was manufactured by St James Gourmet, Farmingdate NY. The ground beef was partial precooked, frozen and packed in bags by the supplier for easier handling. The ground beef was re-blanched at the FMT facility to avoid excessive weight loss during the retort process and thinning of the sauce. Also, the precooking/blanching process removed excessive fat and blood, which otherwise might yield an unacceptable dark product. The cream sauce was made according to the recommended formula in the product specification with the exception that the starch quantity was reduced from 6% to 5.5%. The three main ingredients: "Starch", "Dry Cream" and "Shortening" were manufactured by respectively National Starch, Bridgewater NJ (Purity W or ThermTex), Quality Ingredients, Burnsville MN (Quali-Cream 7211) and Kerry Inc, Beloit WI (NDX-112 V, Item No. I1529).

The trays used in these experiments were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

4. Process Description:

The cream sauce was made in a jacketed Groen Kettle, equipped with high speed mixer and scrape surface agitator using the following procedure (batch size 400 lbs):

1) Mix required quantity of starch in small quantity of cold water and mix vigorously to form a thin slurry.

2) Add remaining quantity of cold water to kettle.
3) Add Dry Cream to kettle and mix vigorously (speed setting: 2) till all dissolved.
4) Add remaining ingredients (except starch slurry) to kettle and mix while heating kettle till product reaches 180 F to 190 F. Use high heat setting
5) Add starch slurry and the final mixture should be heated to 180 F to 190 F and held at this temperature for 5 minutes. (Use low heat setting once 180 F is reached)

The Creamed Ground Beef was made in the Groen Kettle by adding the beef to the already made sauce (~180 F).

6) Add refrigerated precooked ground beef to the sauce and mix with scrape surface agitator till uniformly blended (215 lbs)
7) Heat/Cool blend as required to obtain product temperature required for the experiment
8) Pump blend to the Raque single piston filler hopper.

The trays were placed on the filling conveyor of the Raque Heat Seal Line. The Raque Single Piston Filler filled the tray to either a net weight of 92 or 100 oz. The trays were then conveyed to the Raque Heat Sealer and automatically loaded in the carriers of the sealer. Once in the carrier, the seals were inspected and when necessary wiped. The tray was conveyed at a speed of 8 or 15 trays/min. while seal conditions were maintained at 412 F for either 2.5 or 3.5 seconds. The vacuum condition was controlled by a vacuum timer that opened a vacuum valve for a preset duration. A vacuum time of 1.0 seconds resulted in an approximate vacuum of 20" Hg in the sealing chamber. A vacuum of 0.2 seconds time resulted in an approximate vacuum of 10" Hg in the sealing chamber.

Table #1 displays the various timer settings used for the Raque Heat Sealer. There are three operations occurring in the sealer: "Evacuation", "Sealing" and "Vent". Each operation has two timers, a delay timer and a process timer. The delay timer of each operation starts at the same time, eg at closing of the seal chamber. After the delay timer is timed out, the process timer starts. After the process timer for the sealing operation has timed out, the chamber opens. This means that all operations, including the Vent needs to be completed by the end of the sealing operation. The operation of the Raque heat sealer requires that the vacuum is released during the sealing cycle and therefore does not allow the seal to "set" before the vacuum can be released. This will of course increase the capacity of the sealer but might also cause seal wrinkles due to tension in the lid material. It also means that the equipment relies on a mechanical seal between the internal and exterior of the container during the sealing

process. The seal chamber is brought back to atmospheric pressure while the internal container must remain under the "vacuum condition" in order to control the residual gas level inside the container.

The table also estimates the maximum line speed that could be achieved in any of the timer setups. Using setup #3 with the longest vacuum and seal time reduced the maximum line speed to 15 trays/min which was the highest line speed used in these experiments.

	Setup #1	Setup #2	Setup #3	Setup #4
Vacuum Delay [sec]	0.1	0.1	0.1	0.1
Vacuum Process [sec]	1.0	0.2	1.0	0.2
Sealing Delay [sec]	1.3	0.5	1.3	0.5
Sealing Process [sec]	2.5	2.5	3.5	3.5
Vent Delay [sec]	1.5	0.7	1.5	0.7
Vent Process [sec]	2.3	2.3	3.3	3.3
Max Capacity [Trays/Min]	19	24	15	21

After the sealing process, the trays were inspected for seal defects as identified in MIL-PRF-32004A, (Dated 5-MAR-01). A limited number of trays were evaluated for residual gas content. The data was then analyzed for the response variables residual gas and defective tray. The response variable "defective tray", could either be caused by a critical, major or minor defect, such as open seal (critical) or minor anomaly (minor).

To increase the efficiency of the experiment and cut down on the cost of the raw materials, the Creamed Ground Beef was several times reused by removing the product from the tray and adding it back to the blend kettle.

5. Fractional Factorial Experimental Design:

The objective of the experiments was to investigate the main effect of the factors on the response variables by using two levels (low and high) for every factor. Analysis of the results would reveal the most important factors that influence the response variables. These factors can then be further investigated in a Phase II experimental study to determine in more details the interactions between those variables and the optimal values for each of these factors.

The following variables were selected for this experiment design:

- Product Fill Weight
- Product Viscosity
- Product Temperature
- Line Speed
- Vacuum Time
- Seal Time

Factors	**Creamed Ground Beef Levels**		**Response**
Product fill weight, oz	92	100	**R1**: Number of defective trays
Starch Type	Purity W	Therm Tex	
Product temperature, F	80	140	**R2**: Residual gas
Line speed, trays / min	8	15	
Vacuum Time, sec.	0.2	1	
Sealing Time, sec.	2.5	3.5	

The total number of experiments for a full factorial designed study to determine the main effects and interactions for Creamed Ground Beef is would require 64 ($2^6 = 64$) experimental production runs. The time and expense of such would be such that it was decided to utilize a fractional factorial of 1/4 and reduce the number of experiments to 16 experiments to be more efficient with the resources.

The experimental plan and the results of these runs can be found in Appendix I

6. Data Analysis

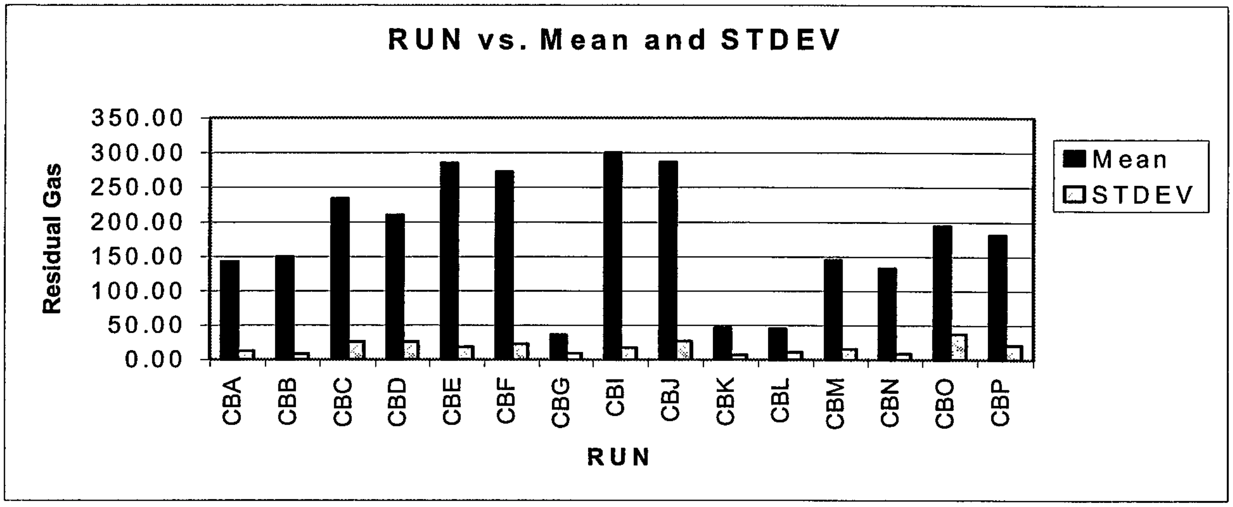
6.1. Residual Gas Data

From each experimental run, six trays were selected for residual gas evaluation. The set of six consisted of four consecutive trays, one of each sealing head, and two random selected trays. The Average and Standard Deviation of the residual gas for each experiment is reported in the table below.

Residual Gas Data per Treatment:

RUN	FILL WEIGHT	Temp. F	SPEED	VAC TIME	SEAL TIME	Starch*	RG Mean	RG STDEV
CBA	92	80	8	1.0	3.5	1	143	13
CBB	92	80	15	1.0	2.5	1	150	8
CBC	100	80	8	0.2	3.5	1	234	27
CBD	100	80	15	0.2	2.5	1	210	26
CBE	92	140	8	0.2	2.5	1	285	18
CBF	92	140	15	0.2	3.5	1	273	23
CBG	100	140	8	1.0	2.5	1	37	9
CBH	100	140	15	1.0	3.5	1	36	13
CBI	92	80	8	0.2	2.5	2	300	18
CBJ	92	80	15	0.2	3.5	2	287	27
CBK	100	80	15	1.0	3.5	2	47	7
CBL	100	80	8	1.0	2.5	2	46	11
CBM	92	140	8	1.0	3.5	2	146	16
CBN	92	140	15	1.0	2.5	2	133	9
CBO	100	140	8	0.2	3.5	2	195	38
CBP	100	140	15	0.2	2.5	2	181	21

*Starch Type: #1 : Purity W Starch
#2 : ThermTex Starch



6.1.1. Residual Gas Data Analysis

6.1.1.1. Summary

The data was further analyzed for by using a multifactor ANOVA analysis. Summary data, obtained from the StatGraphics output can be found in Appendix-II. Based on this data we conclude that:

- The overall F-test was significant at 99% confidence level, indicating that the model as a whole accounts for a significant portion of variability in the response variable (Residual Gas).
- The F-test for Fill Weight, Product Temperature and Vacuum Time were all significant at 99% confidence level. Indicating the means for the different Fill Weight, Temperature and Vacuum Time are statistically not equal.
- The F-test for Speed was significant at 90% confidence level.
- The F-test for Seal Time and Starch Type were not significant at 90% confidence level. Indicating that the means for the different Seal Time and Starch Type are statistically equal.

6.1.1.2. Fill Weight

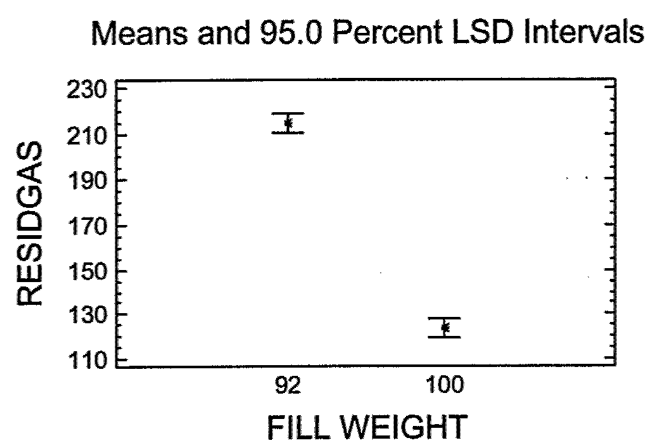
Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Fill Weight. The test indicates, as expected, that the residual gas level is significantly effected by the fill weight. Higher fill weight, and consequently less headspace,

resulted in a lower Residual Gas level. As a consequence, fill weight variation will result in a significant variation of residual gas.

As a result, higher fill weight will require less vacuum to meet the specified maximum residual gas level.

LSD Grouping	Mean	N	Fill Weight, oz
A	123.3	48	100
B	214.5	48	92

*Means with the same letter are not significantly different.



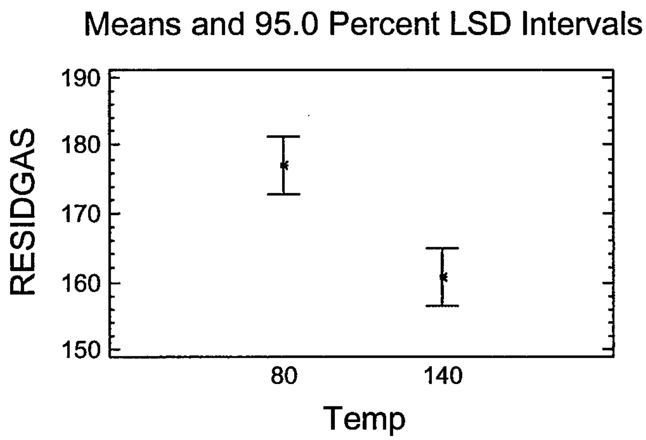
6.1.1.3. Product Temperature

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Product Temperature. The test indicates, as expected, that the residual gas level is significantly effected by the product temperature. Higher product temperature resulted in a lower Residual Gas level. There are two causes for this. First, the gas in the headspace is at approximately the same temperature as the product temperature, but the gas will "shrink" when it is measured at 70 F. Second, at the higher temperature, the vapor pressure of water increases and the gases in the headspace contain therefore more vapor which condenses out at lower temperature, thus reducing the residual gas level.

As result of high temperature filling, less vacuum will be required to meet the maximum head space requirements

LSD Grouping	Mean	N	Product Temperature, F
A	160.6	48	140
B	177.1	48	80

*Means with the same letter are not significantly different.



6.1.1.4. Vacuum

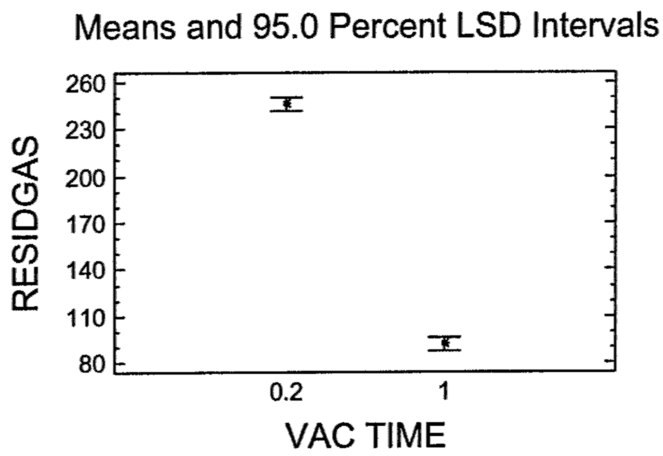
Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Vacuum. As can be seen, the residual gas level is significantly effected by the Vacuum. Longer Vacuum Time and thus Stronger Vacuum, and consequently less gas in the headspace, resulted in a lower Residual Gas level.

As a result, the vacuum timer should be used as the primary control variable to adjust the residual gas level and to compensate for differences in fill weight and product temperature

.

LSD Grouping	Mean	N	Vacuum Time, sec.
A	92.2	48	1.0
B	245.5	48	0.2

*Means with the same letter are not significantly different.



6.1.1.5. Line Speed

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Line Speed. The analysis indicated that, the residual gas level is not significantly effected by the Line Speed. When the confidence interval was dropped to 90%, the analysis did indicate a significant difference. This conclusion was unexpected but could be explained, at least partially, by a small deviation in the average fill weight for the two groups of experiments. The experiments with higher line speed had a slightly higher actual fill weight: (average fill weight: 2705 gram (8 trays/min) and 2715 gram (15 trays/min). This would contributed to at about half of the difference in residual gas level. Other factors might also have contributed, such as better alignment of between the seal heads and carriers at certain speeds and therefore less leakage.

6.1.1.6. Product Viscosity

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Product Viscosity. The analysis indicated that, the residual gas level is not significantly effected by the Product Viscosity. This result was as expected.

6.1.1.7. Seal Time

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Seal Time. The analysis indicated that, the residual gas level is not significantly effected by the Seal Time. This result was as expected.

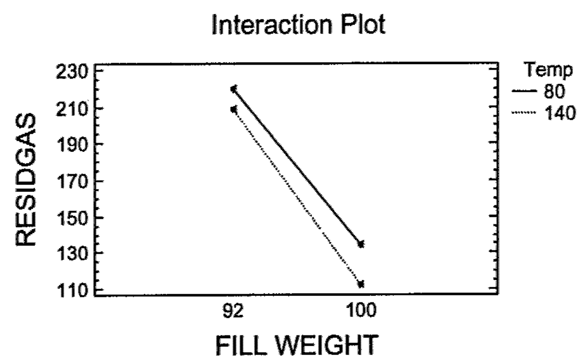
6.1.1.8. Second Order Interactions

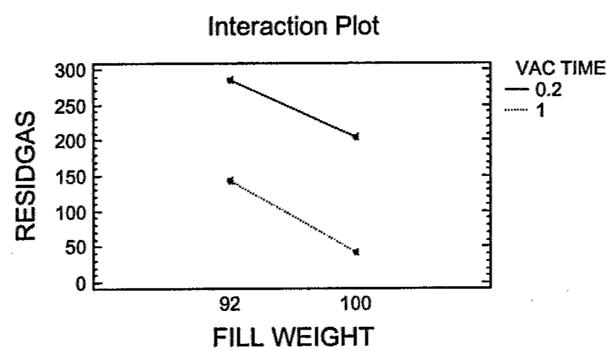
Next, an Anova Analysis was just done using the three most important factors to estimate the second order interactions between these factors and the response variable "residual gas". The data of this analysis can be found in Appendix II. The interaction between Fill Weight and Vacuum Time on Residual Gas are most significant, followed by interaction between Product Temperature and Vacuum Time on Residual Gas. The interaction between Fill Weight and Product Temperature on Residual Gas was not statistical significant. The tables and figures below show the average residual gas as function of the selected variables

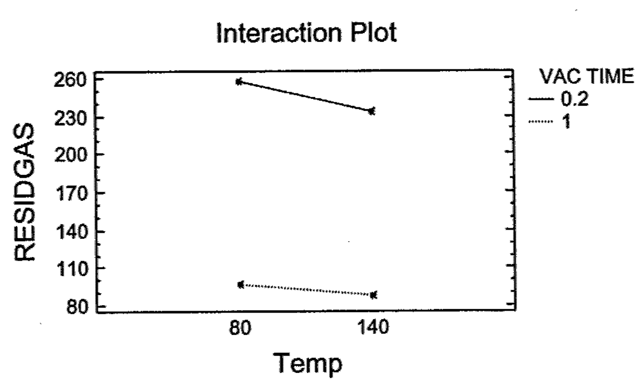
Product Temp [F]	Vacuum Time [sec]	Avg Residual Gas [cc]
80	0.2	258
140	0.2	233
80	1.0	97
140	1.0	88

Fill Weight [oz]	Vacuum Time [sec]	Avg Residual Gas [cc]
92	0.2	286
100	0.2	205
92	1.0	143
100	1.0	41

Product Temp [F]	Fill Weight [oz]	Avg Residual Gas [cc]
80	92	220
140	92	209
80	100	134
140	100	112


Interaction Plot
RESIDGAS
230
210
190
170
150
130
110
92
100
FILL WEIGHT
Temp
80
140


Interaction Plot
RESIDGAS
300
250
200
150
100
50
0
92
100
FILL WEIGHT
VAC TIME
0.2
1


Interaction Plot
RESIDGAS
260
230
200
170
140
110
80
80
140
Temp
VAC TIME
0.2
1

6.2. Seal Defect Data

All the sealed trays were inspected for various defects in the seal area. A seal with one or more defects was considered to be a defective tray and would be removed from the line to be reworked. The most severe defect was used to log the reason for the defective tray. The percent defective tray for each experiment is reported in the table below.

Defective Trays Analysis per Treatment:

RUN	FILL WEIGHT	Temp. F	SPEED	VAC. TIME	SEAL TIME	Starch*	No. of Defect. Trays	Total No. of Trays	% Defective
CBA	92	80	8	1	3.5	1	0	48	0.00
CBB	92	80	15	1	2.5	1	8	48	0.17
CBC	100	80	8	0.2	3.5	1	4	52	0.08
CBD	100	80	15	0.2	2.5	1	2	48	0.04
CBE	92	140	8	0.2	2.5	1	46	48	0.96
CBF	92	140	15	0.2	3.5	1	10	51	0.20
CBG	100	140	8	1	2.5	1	29	42	0.69
CBH	100	140	15	1	3.5	1	7	42	0.17
CBI	92	80	8	0.2	2.5	2	2	45	0.04
CBJ	92	80	15	0.2	3.5	2	3	44	0.07
CBK	100	80	15	1	3.5	2	7	49	0.14
CBL	100	80	8	1	2.5	2	2	45	0.04
CBM	92	140	8	1	3.5	2	22	70	0.31
CBN	92	140	15	1	2.5	2	39	49	0.80
CBO	100	140	8	0.2	3.5	2	3	49	0.06
CBP	100	140	15	0.2	2.5	2	27	48	0.56

*Starch Type: #1 : Purity W Starch
#2 : ThermTex Starch

6.2.1. Defective Tray Data Analysis

6.2.1.1. Summary

The data was analyzed on the number of defective trays in each experiment by using a multifactor ANOVA analysis. Summary data, obtained from the StatGraphics output can be found in Appendix-III. Based on this data we can conclude that:

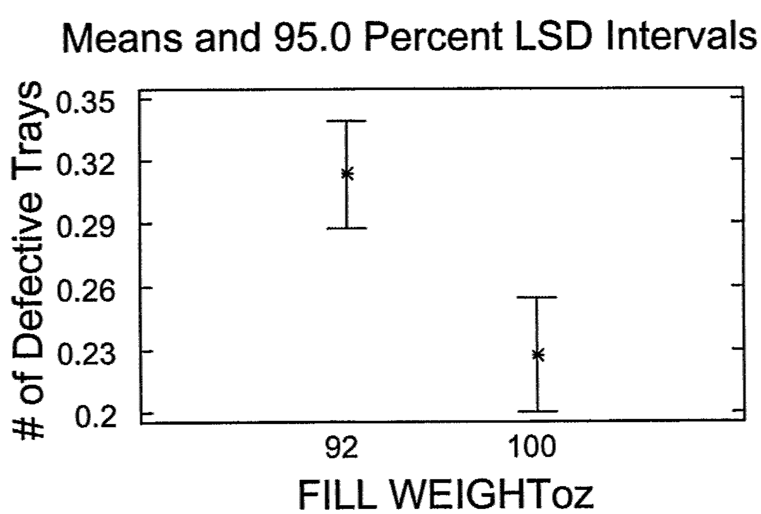
- The F-test for the parameters: Fill Weight, Product Temp. and Seal Time were significant at 99% confidence level, indicating the means at the different factor levels are not equal.
- The F-test for Line Speed, Vacuum Time and Starch Type were not significant at 90% confidence level, indicating the means at the different Line Speed, Vacuum Time and Starch Type are not different.

6.2.1.2. Fill Weight

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Fill Weight. The output from the test indicated a lower defect rate when the tray was sealed with 100 oz Fill Weight.. The reason for this is that the film is less stretched when the vacuum is released and can rest on the product.

LSD Grouping	Mean	N	Fill Weight, oz
A	0.227	375	100
B	0.313	403	92

*Means with the same letter are not significantly different.

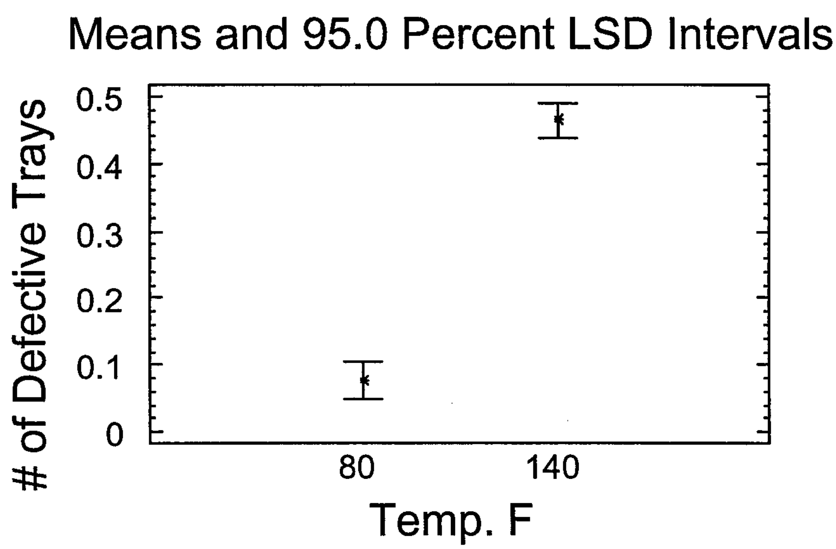


6.2.1.3. Product Temperature

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Product Temperature.. The output from the test indicated a lower defect rate when the tray was sealed with product that had a temperature of 80 F. The reason for this is that higher product temperature caused moisture condensation in the seal area. This condensed moisture is then incorporated in the seal melt and when the seal pressure is released. At that time the incorporated moisture forms tiny steam bubbles, separating the film from the tray to form the so called anomalies

LSD Grouping	Mean	N	Product Temperature, F
A	0.46	399	140
B	0.076	379	80

*Means with the same letter are not significantly different.



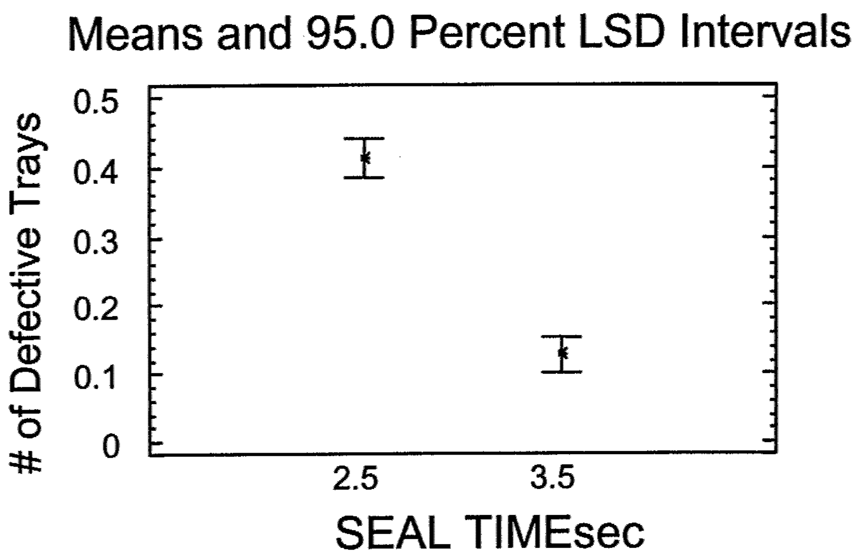
6.2.1.4. Seal Time

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Seal Time.. The output from the test indicated a lower defect rate when the tray was sealed with a 3.5 second dwell time. The longer seal dwell times tend to push out the top layer of molten poly propylene, and in case where there is moisture entrapment, it

also tends to push out this moisture. The moisture is burned off and what ever moisture remains tend to form small anomalies that are located in a ridge on the inside of the seal. We did not score these as defects, as they were not part of the first 1/16" of the seal.

LSD Grouping	Mean	N	Seal Time, sec.
A	0.128	404	3.5
B	0.413	374	2.5

*Means with the same letter are not significantly different.



6.2.1.5. Vacuum

Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Vacuum. The analysis indicated that, the rate of defective trays is not significantly effected by the level of Vacuum.

6.2.1.6. Line Speed

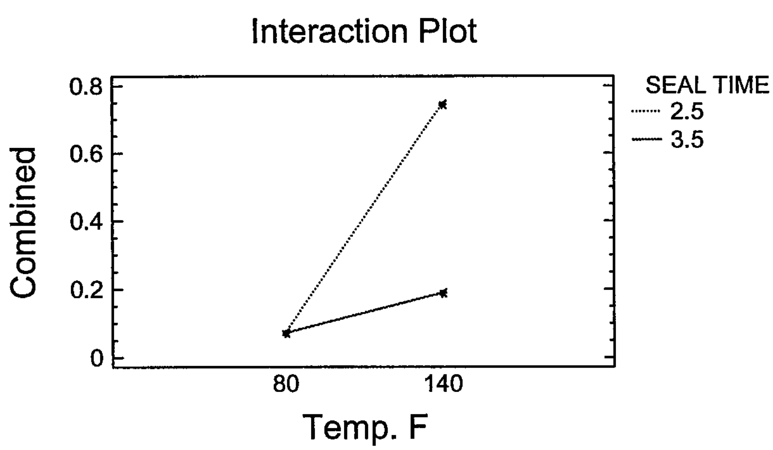
Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Line Speed. The analysis indicated that, the rate of defective trays is not significantly effected by the Line Speed.

6.2.1.7. Product Viscosity

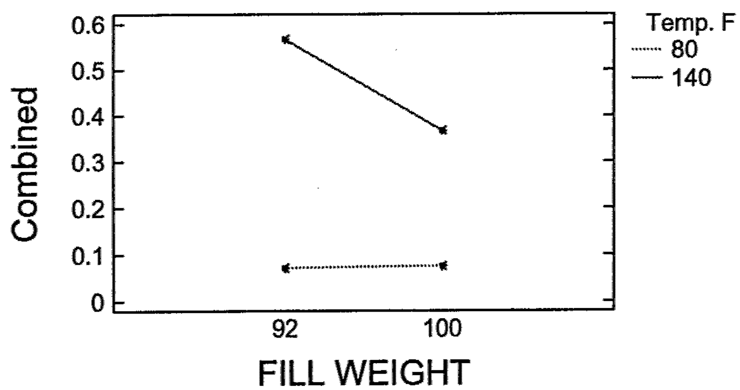
Multiple comparison test (LSD Test) at 95% confidence level was used to compare between the two levels of Product Viscosity. The analysis indicated that, the rate of defective trays is not significantly effected by the Product Viscosity.

6.2.1.8. Second Order Interactions

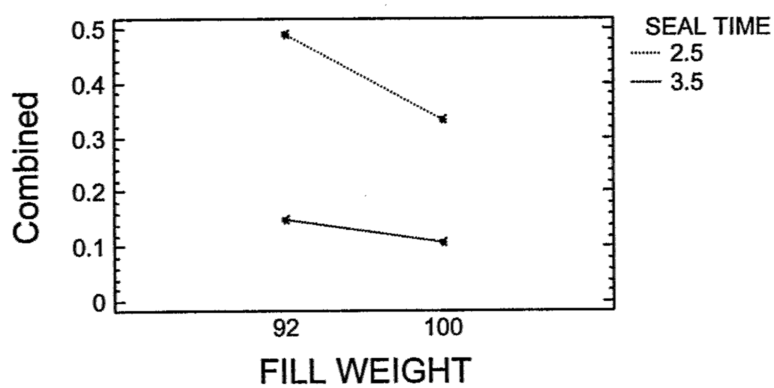
Next, an Anova Analysis was just done using the three most important factors to determine the second order interactions between these factors and the response variable "Defective Tray". The data of this analysis can be found in Appendix III. The analysis shows that the interaction between Fill Weight and Product Temperature as well as Product Temperature and Seal Time on the rate of Defective Trays are significant (99% confidence interval), followed by interaction between Fill Weight and Seal Time on rate of Defective Trays (95% confidence interval).



Interaction Plot



Interaction Plot



7. Conclusions

- The pre-retort residual gas in the tray is primarily determined by the Vacuum, Fill Weight and Product Temperature
- The defective trays due to seal defects were primarily determined by Seal Time, Fill Weight and Product Temperature.
- Increased product temperature caused condensation in the seal is which lead to anomalies in the seal area.
- Increased seal time did reduce the problems of moisture entrapment of the seal. It appears that the moisture is pushed to the outside edges of the seal. In case of the 3.5 sec seal time, most seal defects were minor anomalies located at the inner edge of the seal, followed by a nice, wide seal.
- Higher Fill Weight tended to reduce the rate of defective trays. It is hypothesized that the film is less stretched, reducing the chance for delaminations and wrinkles
- Vacuum was not identified as the primary cause for defective trays. Good seals can be made under high vacuum as long as the fill weight is adequate to support the film after the vacuum is released.

8. References

- Hicks, C. R., and Turner, Jr., K. V. (1999), Fundamental Concepts in the Design of Experiments, 5th edition. New York: Oxford University Press, Inc.
- Dean, A. and Voss, D. (1999), Design and Analysis of Experiments, New York: Springer-Verlag, Inc.
- STATGRAPHICS Plus (2000), A Manugistics Product, Version 5, Manugistics, Inc., Maryland, USA.

9. Appendix

Appendix I: Experimental Plan and Results for Creamed Ground Beef

Appendix II: Residual Gas Data Analysis for Creamed Ground Beef

Appendix III: Seal Defect Analysis for Creamed Ground Beef

Appendix I

Experimental Plan and Results
for
Creamed Ground Beef

Filling Experiments

Creamed Ground Beef

At the day of experiments, one batch of sauce for Creamed Ground Beef will be manufactured (400 lb). A sample of the sauce will be taken for viscosity measurement. Steam will be turned off and pre cooked ground beef will be added (215 lb). After the batch is uniformly mixed, the product temperature will be measured. The required temperature range will be 70-90 F for the 80 F product temperature condition and 130-150 F for the 140 F condition. The product will then be transferred via pump to the Raque filler as needed. Forty-eight trays will be filled and sealed for each experiment. Random samples will be taken from the experiment for QC testing (residual gas, net-weight). The lid of the remaining containers will be removed by cutting the lid on the inside of the seal area. The product will be removed from the container and dumped back into the final mixing kettle. The product is reheated to the required experimental temperature and the second run is made. Repeat above process till four runs have been made. Discard product at end of the day. The produced containers will be cleaned and inspected for seal defects at a later date.

Purity W

Experimental Code	Product Fill Weight	Product Temperature	Line Speed	Vacuum time	Sealing Time
CBA-1	92 oz	80 F	8 tray/min	1.0 sec	3.5 sec
CBB-1	92	80	15	1.0	2.5
CBC-1	100	80	8	0.2	3.5
CBD-1	100	80	15	0.2	2.5
CBE-1	92	140	8	0.2	2.5
CBF-1	92	140	15	0.2	3.5
CBG-1	100	140	8	1.0	2.5
CBH-1	100	140	15	1.0	3.5

ThermTex

Experimental Code	Product Fill Weight	Product Temperature	Line Speed	Vacuum time	Sealing Time
CBI-1	92 oz	80 F	8 tray/min	0.2 sec	2.5 sec
CBJ-1	92	80	15	0.2	3.5
CBK-1	100	80	15	1.0	3.5
CBL-1	100	80	8	1.0	2.5
CBM-1	92	140	8	1.0	3.5
CBN-1	92	140	15	1.0	2.5
CBO-1	100	140	8	0.2	3.5
CBP-1	100	140	15	0.2	2.5

Test ID	CBA	CBB	CBC	CBD	CBE	CBF
Line Speed	8	15	8	15	8	15
Seal Temp	412	412	412	412	412	412
Seal Pressure	80	80	80	80	80	80
Seal Time	3.5	2.5	3.5	2.5	2.5	3.5
Vacuum Time	1.0	1.0	0.2	0.2	0.2	0.2
Vacuum Press	20	20	10	10	10	10
Raque Volume						
Product Temp	90	88	84	82	148	144
Starch	Purity W	Purity W	Purity W	Purity W	Purity W	Purity W
Fill Weight [oz]	92	92	100	100	92	92
Fill Weight avg	2593	2591	2816	2791	2620	2632
Fill Weight std	4	3	6	12	1	4
Residual Gas avg	143	150	234	210	285	273
Residual Gas std	13	8	27	26	18	23
Trays produced	48	48	52	48	48	51
Open Seals						
Seal Wrinkles						
Abrasion						
Delamination CR						
Delamination MA						
Delamination MI						
Anomalies CR		4	4	4	1	
Anomalies MI		4			45	10
Narrow Seals						
Trays Accepted	48	40	48	46	2	41

Test ID	CBG	CBH	CBI	CBJ	CBK	CBL
Line Speed	8	15	8	15	15	8
Seal Temp	412	412	412	412	412	412
Seal Pressure	80	80	80	80	80	80
Seal Time	2.5	3.5	2.5	3.5	3.5	2.5
Vacuum Time	1.0	1.0	0.2	0.2	1.0	1.0
Vacuum Press	20	20	10	10	20	20
Raque Volume						
Product Temp	152	134	84	80	88	84
Starch	Purity W	Purity W	Thermtex	Thermtex	Thermtex	Thermtex
Fill Weight [oz]	100	100	92	92	100	100
Fill Weight avg	2823	2837	2576	2573	2805	2771
Fill Weight std	3	5	24	13	5	19
Residual Gas avg	37	36	300	287	47	46
Residual Gas std	9	13	18	27	7	11
Trays produced	42	42	45	44	49	45
Open Seals						
Seal Wrinkles						
Abrasion						
Delamination CR						1
Delamination MA						
Delamination MI						
Anomalies CR	4	2	2	3	6	
Anomalies MI	25	5				
Narrow Seals					1	1
Trays Accepted	13	35	43	41	42	43

Test ID	CBM	CBN	CBO	CBP
Line Speed	8	15	8	15
Seal Temp	412	412	412	412
Seal Pressure	80	80	80	80
Seal Time	3.5	2.5	3.5	2.5
Vacuum Time	1.0	1.0	0.2	0.2
Vacuum Press	20	20	10	10
Raque Volume				
Product Temp	146	142	142	138
Starch	Thermtex	Thermtex	Thermtex	Thermtex
Fill Weight [oz]	92	92	100	100
Fill Weight avg	2622	2632	2824	2858
Fill Weight std	8	4	40	4
Residual Gas avg	146	133	195	181
Residual Gas std	16	9	38	21
Trays produced	70	49	49	48
Open Seals				
Seal Wrinkles				
Abrasion				
Delamination CR	1			1
Delamination MA				
Delamination MI				
Anomalies CR	13	12	2	8
Anomalies MI	8	25	1	18
Narrow Seals		2		
Trays Accepted	48	10	46	21

Appendix II

Residual Gas Data Analysis
for
Creamed Ground Beef

RUN	FILL WEIGHT	Temp. F	SPEED	VAC TIME	SEAL TIME	Starch	RESIDGAS
CBA	92	80	8	1	3.5	1	134
CBA	92	80	8	1	3.5	1	154
CBA	92	80	8	1	3.5	1	164
CBA	92	80	8	1	3.5	1	134
CBA	92	80	8	1	3.5	1	140
CBA	92	80	8	1	3.5	1	134
CBB	92	80	15	1	2.5	1	138
CBB	92	80	15	1	2.5	1	150
CBB	92	80	15	1	2.5	1	156
CBB	92	80	15	1	2.5	1	154
CBB	92	80	15	1	2.5	1	160
CBB	92	80	15	1	2.5	1	142
CBC	100	80	8	0.2	3.5	1	260
CBC	100	80	8	0.2	3.5	1	220
CBC	100	80	8	0.2	3.5	1	255
CBC	100	80	8	0.2	3.5	1	250
CBC	100	80	8	0.2	3.5	1	190
CBC	100	80	8	0.2	3.5	1	230
CBD	100	80	15	0.2	2.5	1	245
CBD	100	80	15	0.2	2.5	1	210
CBD	100	80	15	0.2	2.5	1	185
CBD	100	80	15	0.2	2.5	1	230
CBD	100	80	15	0.2	2.5	1	215
CBD	100	80	15	0.2	2.5	1	175
CBE	92	140	8	0.2	2.5	1	265
CBE	92	140	8	0.2	2.5	1	300
CBE	92	140	8	0.2	2.5	1	300
CBE	92	140	8	0.2	2.5	1	270
CBE	92	140	8	0.2	2.5	1	270
CBE	92	140	8	0.2	2.5	1	305
CBF	92	140	15	0.2	3.5	1	250
CBF	92	140	15	0.2	3.5	1	260
CBF	92	140	15	0.2	3.5	1	285
CBF	92	140	15	0.2	3.5	1	275
CBF	92	140	15	0.2	3.5	1	255
CBF	92	140	15	0.2	3.5	1	310
CBG	100	140	8	1	2.5	1	34
CBG	100	140	8	1	2.5	1	40
CBG	100	140	8	1	2.5	1	44
CBG	100	140	8	1	2.5	1	48
CBG	100	140	8	1	2.5	1	24
CBG	100	140	8	1	2.5	1	30
CBH	100	140	15	1	3.5	1	24
CBH	100	140	15	1	3.5	1	24
CBH	100	140	15	1	3.5	1	38
CBH	100	140	15	1	3.5	1	36
CBH	100	140	15	1	3.5	1	60
CBH	100	140	15	1	3.5	1	36

CBI	92	80	8	0.2	2.5	2	300
CBI	92	80	8	0.2	2.5	2	305
CBI	92	80	8	0.2	2.5	2	280
CBI	92	80	8	0.2	2.5	2	310
CBI	92	80	8	0.2	2.5	2	325
CBI	92	80	8	0.2	2.5	2	280
CBJ	92	80	15	0.2	3.5	2	320
CBJ	92	80	15	0.2	3.5	2	250
CBJ	92	80	15	0.2	3.5	2	270
CBJ	92	80	15	0.2	3.5	2	270
CBJ	92	80	15	0.2	3.5	2	310
CBJ	92	80	15	0.2	3.5	2	300
CBK	100	80	15	1	3.5	2	46
CBK	100	80	15	1	3.5	2	44
CBK	100	80	15	1	3.5	2	56
CBK	100	80	15	1	3.5	2	44
CBK	100	80	15	1	3.5	2	54
CBK	100	80	15	1	3.5	2	38
CBL	100	80	8	1	2.5	2	56
CBL	100	80	8	1	2.5	2	62
CBL	100	80	8	1	2.5	2	40
CBL	100	80	8	1	2.5	2	34
CBL	100	80	8	1	2.5	2	42
CBL	100	80	8	1	2.5	2	40
CBM	92	140	8	1	3.5	2	154
CBM	92	140	8	1	3.5	2	164
CBM	92	140	8	1	3.5	2	120
CBM	92	140	8	1	3.5	2	138
CBM	92	140	8	1	3.5	2	156
CBM	92	140	8	1	3.5	2	142
CBN	92	140	15	1	2.5	2	136
CBN	92	140	15	1	2.5	2	136
CBN	92	140	15	1	2.5	2	116
CBN	92	140	15	1	2.5	2	140
CBN	92	140	15	1	2.5	2	132
CBN	92	140	15	1	2.5	2	138
CBO	100	140	8	0.2	3.5	2	270
CBO	100	140	8	0.2	3.5	2	196
CBO	100	140	8	0.2	3.5	2	180
CBO	100	140	8	0.2	3.5	2	172
CBO	100	140	8	0.2	3.5	2	170
CBO	100	140	8	0.2	3.5	2	180
CBP	100	140	15	0.2	2.5	2	200
CBP	100	140	15	0.2	2.5	2	170
CBP	100	140	15	0.2	2.5	2	208
CBP	100	140	15	0.2	2.5	2	178
CBP	100	140	15	0.2	2.5	2	182
CBP	100	140	15	0.2	2.5	2	150

Multiple Regression Analysis

Dependent variable: RESIDGAS

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1422.96	53.4381	26.6281	0.0000
FILL WEIGHT	-11.4115	0.524613	-21.7521	0.0000
SEAL TIME	2.33333	4.19691	0.555965	0.5796
SPEED	-1.22024	0.599558	-2.03523	0.0448
Starch	-4.25	4.19691	-1.01265	0.3140
Temp	-0.274306	0.0699484	-3.92154	0.0002
VAC TIME	-191.667	5.24613	-36.5349	0.0000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	773103.0	6	128850.0	304.80	0.0000
Residual	37623.5	89	422.736		
Total (Corr.)	810727.0	95			

R-squared = 95.3593 percent
R-squared (adjusted for d.f.) = 95.0464 percent
Standard Error of Est. = 20.5606
Mean absolute error = 15.7708
Durbin-Watson statistic = 1.76905 (P=0.0433)
Lag 1 residual autocorrelation = 0.094888

Multifactor ANOVA - RESIDGAS

Analysis Summary

Dependent variable: RESIDGAS
Factors:
FILL WEIGHT
SEAL TIME
SPEED
Starch
Temp
VAC TIME

Number of complete cases: 96

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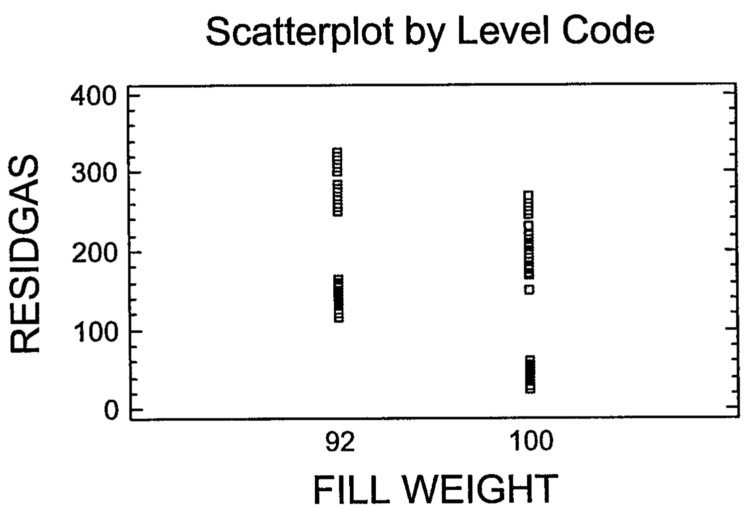
This procedure performs a multifactor analysis of variance for RESIDGAS. It constructs various tests and graphs to determine which factors have a statistically significant effect on RESIDGAS. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.



Analysis of Variance for RESIDGAS - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:FILL WEIGHT	200020.0	1	200020.0	473.16	0.0000
B:SEAL TIME	130.667	1	130.667	0.31	0.5796
C:SPEED	1751.04	1	1751.04	4.14	0.0448
D:Starch	433.5	1	433.5	1.03	0.3140
E:Temp	6501.04	1	6501.04	15.38	0.0002
F:VAC TIME	564267.0	1	564267.0	1334.80	0.0000
RESIDUAL	37623.5	89	422.736		

TOTAL (CORRECTED)	810727.0	95

All F-ratios are based on the residual mean square error.

The StatAdvisor

The ANOVA table decomposes the variability of RESIDGAS into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 4 P-values are less than 0.05, these factors have a statistically significant effect on RESIDGAS at the 95.0% confidence level.

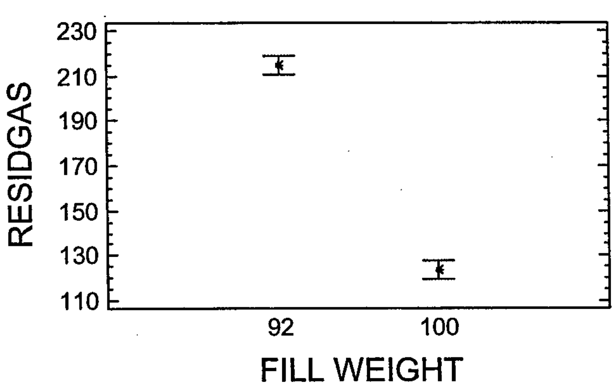
Table of Least Squares Means for RESIDGAS
with 95.0 Percent Confidence Intervals

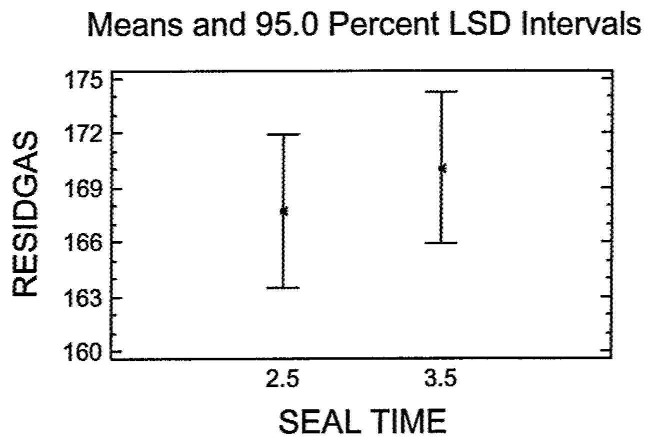
Level	Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN	96	168.875			
FILL WEIGHT					
92	48	214.521	2.96766	208.624	220.418
100	48	123.229	2.96766	117.332	129.126
SEAL TIME					
2.5	48	167.708	2.96766	161.812	173.605
3.5	48	170.042	2.96766	164.145	175.938
SPEED					
8	48	173.146	2.96766	167.249	179.043
15	48	164.604	2.96766	158.707	170.501
Starch					
1	48	171.0	2.96766	165.103	176.897
2	48	166.75	2.96766	160.853	172.647
Temp					
80	48	177.104	2.96766	171.207	183.001
140	48	160.646	2.96766	154.749	166.543
VAC TIME					
0.2	48	245.542	2.96766	239.645	251.438
1	48	92.2083	2.96766	86.3116	98.105

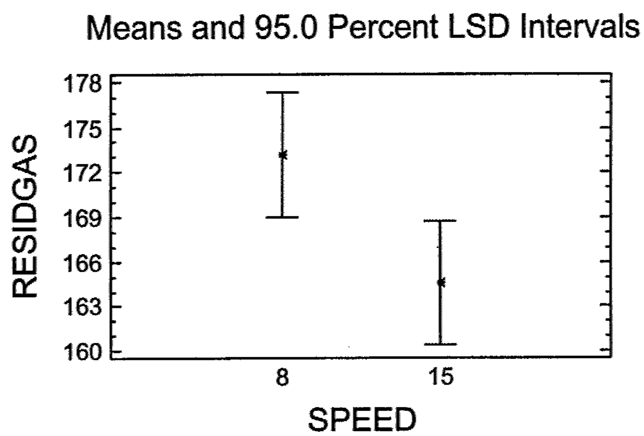
The StatAdvisor

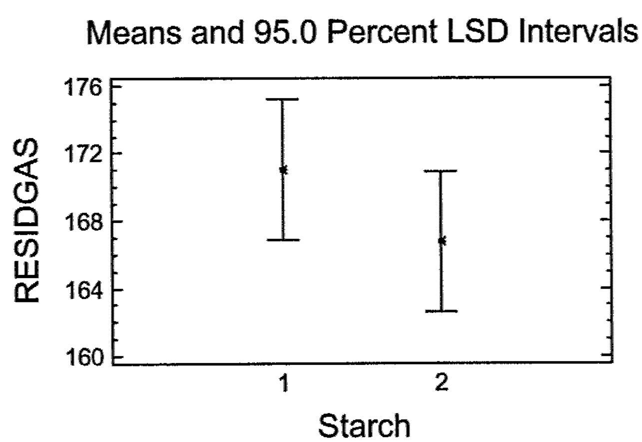
This table shows the mean RESIDGAS for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.

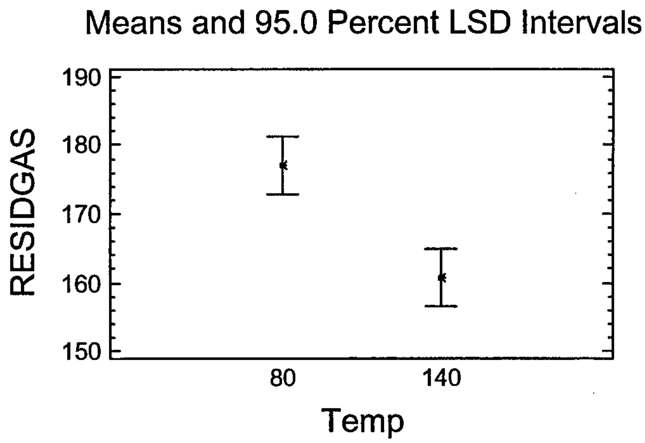
Means and 95.0 Percent LSD Intervals

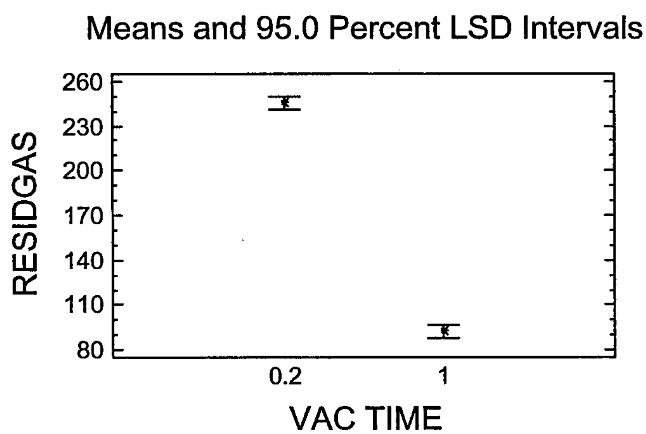



Means and 95.0 Percent LSD Intervals
RESIDGAS
175
172
169
166
163
160
2.5
3.5
SEAL TIME


Means and 95.0 Percent LSD Intervals
RESIDGAS
178
175
172
169
166
163
160
8
15
SPEED


Means and 95.0 Percent LSD Intervals
RESIDGAS
176
172
168
164
160
1
2
Starch


Means and 95.0 Percent LSD Intervals
RESIDGAS
190
180
170
160
150
80
140
Temp


Means and 95.0 Percent LSD Intervals
RESIDGAS
260
230
200
170
140
110
80
0.2
1
VAC TIME

Interaction Analysis on the three most important factors

Fill Weight	Temp	Vacuum Time	Res Gas Avg [cc]	Res Gas Std [cc]
92	80	0.2	293	23
92	80	1.0	147	11
92	140	0.2	279	21
92	140	1.0	139	14
100	80	0.2	222	28
100	80	1.0	46	9
100	140	0.2	188	30
100	140	1.0	37	11

```
Multifactor ANOVA - RESIDGAS

Analysis Summary

Dependent variable: RESIDGAS
Factors:
        FILL WEIGHT
        Temp
        VAC TIME

Number of complete cases: 96


The StatAdvisor
---------------
   This procedure performs a multifactor analysis of variance for
RESIDGAS.  It constructs various tests and graphs to determine which
factors have a statistically significant effect on RESIDGAS.  It also
tests for significant interactions amongst the factors, given
sufficient data.  The F-tests in the ANOVA table will allow you to
identify the significant factors.  For each significant factor, the
Multiple Range Tests will tell you which means are significantly
different from which others.  The Means Plot and Interaction Plot will
help you interpret the significant effects.  The Residual Plots will
help you judge whether the assumptions underlying the analysis of
variance are violated by the data.



Analysis of Variance for RESIDGAS - Type III Sums of Squares
--------------------------------------------------------------------------------
Source                    Sum of Squares     Df    Mean Square    F-Ratio     P-Value
--------------------------------------------------------------------------------
MAIN EFFECTS
 A:FILL WEIGHT                  200020.0      1       200020.0     505.99      0.0000
 B:Temp                          6501.04      1        6501.04      16.45      0.0001
 C:VAC TIME                     564267.0      1       564267.0    1427.41      0.0000

INTERACTIONS
 AB                                726.0      1          726.0       1.84      0.1788
 AC                              2542.04      1        2542.04       6.43      0.0130
 BC                              1488.38      1        1488.38       3.77      0.0555

RESIDUAL                         35182.3     89        395.307
```

TOTAL (CORRECTED)	810727.0	95

All F-ratios are based on the residual mean square error.

The StatAdvisor

The ANOVA table decomposes the variability of RESIDGAS into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 4 P-values are less than 0.05, these factors have a statistically significant effect on RESIDGAS at the 95.0% confidence level.

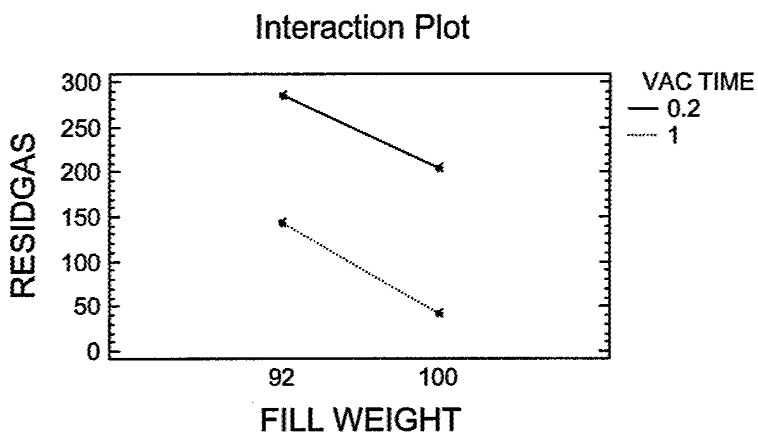
Table of Least Squares Means for RESIDGAS
with 95.0 Percent Confidence Intervals

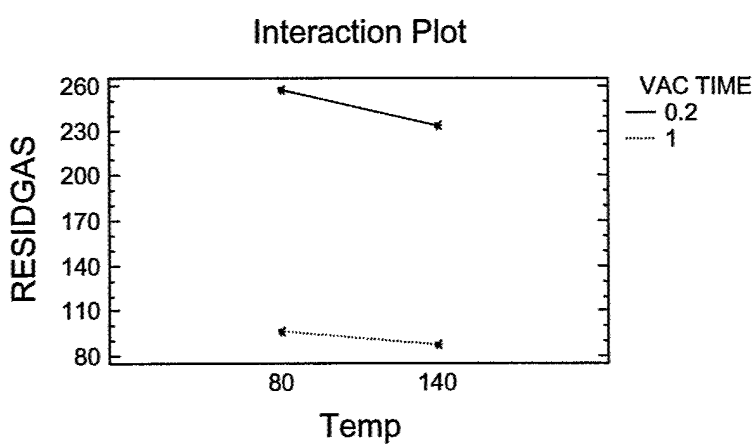
Level		Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN		96	168.875			
FILL WEIGHT						
92		48	214.521	2.86977	208.819	220.223
100		48	123.229	2.86977	117.527	128.931
Temp						
80		48	177.104	2.86977	171.402	182.806
140		48	160.646	2.86977	154.944	166.348
VAC TIME						
0.2		48	245.542	2.86977	239.839	251.244
1		48	92.2083	2.86977	86.5062	97.9105
FILL WEIGHT by Temp						
92	80	24	220.0	4.05846	211.936	228.064
92	140	24	209.042	4.05846	200.978	217.106
100	80	24	134.208	4.05846	126.144	142.272
100	140	24	112.25	4.05846	104.186	120.314
FILL WEIGHT by VAC TIME						
92	0.2	24	286.042	4.05846	277.978	294.106
92	1	24	143.0	4.05846	134.936	151.064
100	0.2	24	205.042	4.05846	196.978	213.106
100	1	24	41.4167	4.05846	33.3526	49.4808
Temp by VAC TIME						
80	0.2	24	257.708	4.05846	249.644	265.772
80	1	24	96.5	4.05846	88.4359	104.564
140	0.2	24	233.375	4.05846	225.311	241.439
140	1	24	87.9167	4.05846	79.8526	95.9808

The StatAdvisor

This table shows the mean RESIDGAS for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.


Interaction Plot
230
210
190
170
150
130
110
RESIDGAS
92
100
FILL WEIGHT
Temp
80
140


Interaction Plot
300
250
200
150
100
50
0
RESIDGAS
92
100
FILL WEIGHT
VAC TIME
0.2
1


Interaction Plot
260
230
200
170
140
110
80
RESIDGAS
80
140
Temp
VAC TIME
0.2
1

Appendix III

Seal Defects Analysis
for
Creamed Ground Beef

Defective Trays Analysis per Treatment:

RUN	FILL WEIGHT	Temp. F	SPEED	VAC. TIME	SEAL TIME	Starch*	No. of Defect. Trays	Total No. of Trays	Defective Ratio
CBA	92	80	8	1	3.5	1	0	48	0.00
CBB	92	80	15	1	2.5	1	8	48	0.17
CBC	100	80	8	0.2	3.5	1	4	52	0.08
CBD	100	80	15	0.2	2.5	1	2	48	0.04
CBE	92	140	8	0.2	2.5	1	46	48	0.96
CBF	92	140	15	0.2	3.5	1	10	51	0.20
CBG	100	140	8	1	2.5	1	29	42	0.69
CBH	100	140	15	1	3.5	1	7	42	0.17
CBI	92	80	8	0.2	2.5	2	2	45	0.04
CBJ	92	80	15	0.2	3.5	2	3	44	0.07
CBK	100	80	15	1	3.5	2	7	49	0.14
CBL	100	80	8	1	2.5	2	2	45	0.04
CBM	92	140	8	1	3.5	2	22	70	0.31
CBN	92	140	15	1	2.5	2	39	49	0.80
CBO	100	140	8	0.2	3.5	2	3	49	0.06
CBP	100	140	15	0.2	2.5	2	27	48	0.56

*Starch Type: #1 : Purity W Starch
#2 : ThermTex Starch

Seal Defects Analysis of CGB with Two-Starch Types:

Multifactor ANOVA - Combined

Analysis Summary
Dependent variable: Combined
Factors:
- FILL WEIGHT
- Temp. F
- SPEED
- VAC TIME
- SEAL TIME
- Starch

Number of complete cases: 778

The StatAdvisor

This procedure performs a multifactor analysis of variance for Combined. It constructs various tests and graphs to determine which factors have a statistically significant effect on Combined. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.

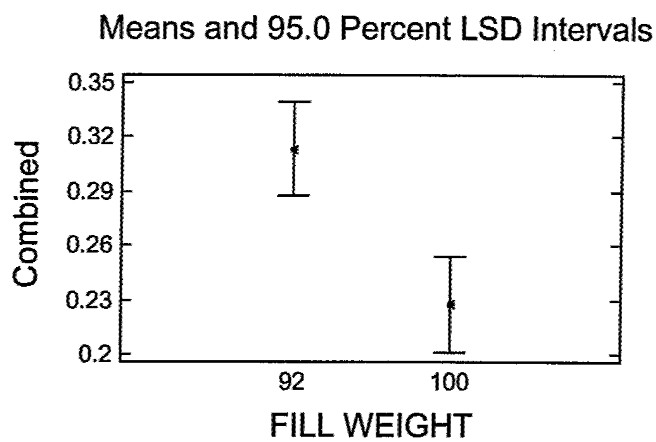
Analysis of Variance for Combined - Type III Sums of Squares

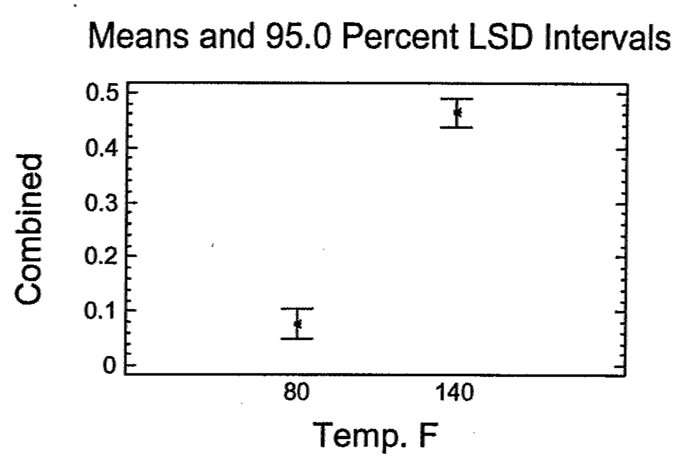
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:FILL WEIGHT	1.42233	1	1.42233	10.21	0.0014
B:Temp. F	28.8983	1	28.8983	207.48	0.0000
C:SPEED	0.00107792	1	0.00107792	0.01	0.9299
D:VAC TIME	0.300219	1	0.300219	2.16	0.1421
E:SEAL TIME	15.6859	1	15.6859	112.62	0.0000
F:Starch	0.237329	1	0.237329	1.70	0.1918
RESIDUAL	107.386	771	0.139281		
TOTAL (CORRECTED)	153.775	777			

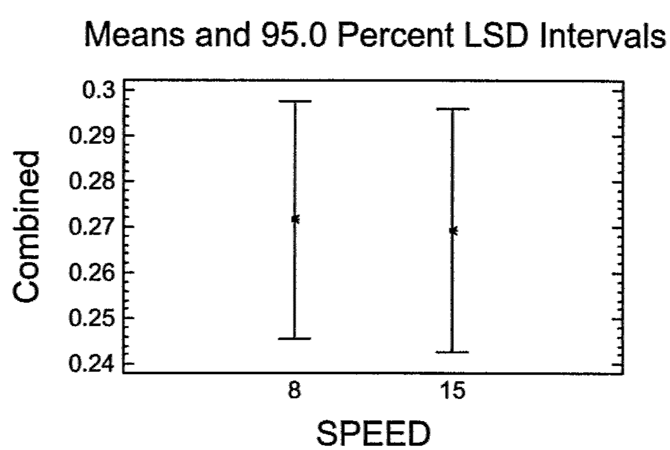
All F-ratios are based on the residual mean square error.

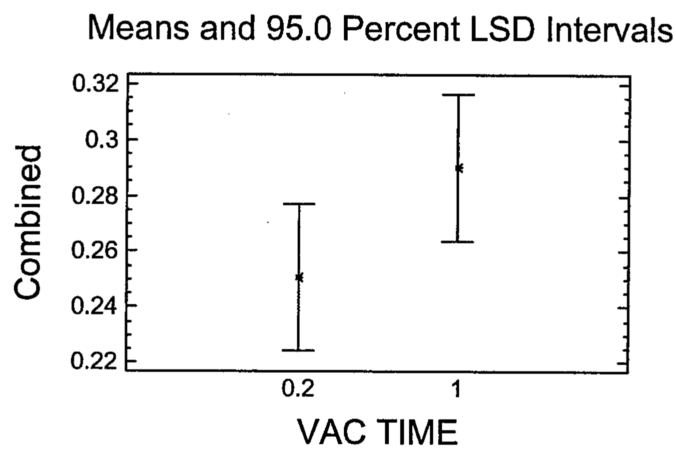
The StatAdvisor

The ANOVA table decomposes the variability of Combined into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 3 P-values are less than 0.05, these factors have a statistically significant effect on Combined at the 95.0% confidence level.

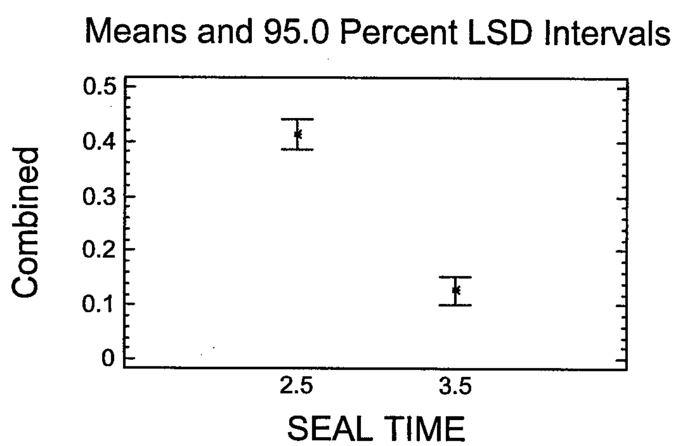

Means and 95.0 Percent LSD Intervals
Combined
0.35
0.32
0.29
0.26
0.23
0.2
92
100
FILL WEIGHT


Means and 95.0 Percent LSD Intervals
Combined
0.5
0.4
0.3
0.2
0.1
0
80
140
Temp. F

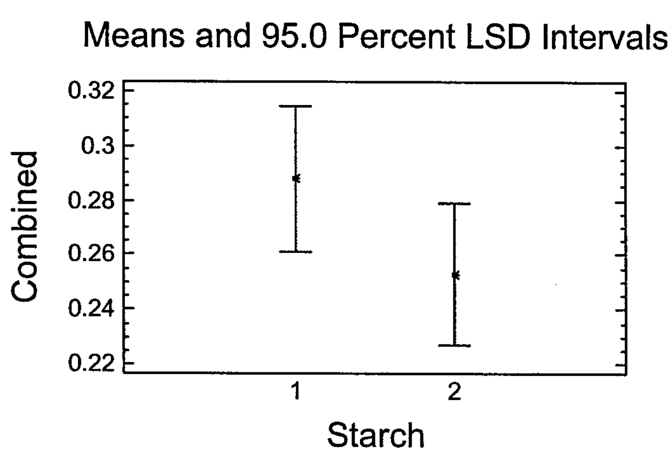

Means and 95.0 Percent LSD Intervals
Combined
0.3
0.29
0.28
0.27
0.26
0.25
0.24
8
15
SPEED



Means and 95.0 Percent LSD Intervals
Combined
0.32
0.3
0.28
0.26
0.24
0.22
0.2
1
VAC TIME



Means and 95.0 Percent LSD Intervals
Combined
0.5
0.4
0.3
0.2
0.1
0
2.5
3.5
SEAL TIME



Means and 95.0 Percent LSD Intervals
Combined
0.32
0.3
0.28
0.26
0.24
0.22
1
2
Starch

Multiple Range Tests for Combined by FILL WEIGHT

Method: 95.0 percent LSD

FILL WEIGHT	Count	LS Mean	LS Sigma	Homogeneous Groups
100	375	0.227451	0.0192953	X
92	403	0.31334	0.0186686	X

Contrast	Difference	+/- Limits
92 - 100	*0.0858888	0.0526782

* denotes a statistically significant difference.

Multiple Range Tests for Combined by Temp. F

Method: 95.0 percent LSD

Temp. F	Count	LS Mean	LS Sigma	Homogeneous Groups
80	379	0.0768726	0.0191803	X
140	399	0.463918	0.0187819	X

Contrast	Difference	+/- Limits
80 - 140	*-0.387045	0.0526648

* denotes a statistically significant difference.

Multiple Range Tests for Combined by SPEED

Method: 95.0 percent LSD

SPEED	Count	LS Mean	LS Sigma	Homogeneous Groups
15	378	0.269215	0.0191985	X
8	400	0.271576	0.0187389	X

Contrast	Difference	+/- Limits
8 - 15	0.00236085	0.052598

* denotes a statistically significant difference.

Multiple Range Tests for Combined by VAC TIME

Method: 95.0 percent LSD

VAC TIME	Count	LS Mean	LS Sigma	Homogeneous Groups
0.2	385	0.250676	0.019032	X
1	393	0.290115	0.0189269	X

Contrast	Difference	+/- Limits
0.2 - 1	-0.0394389	0.0526503

* denotes a statistically significant difference.

Multiple Range Tests for Combined by SEAL TIME

Method: 95.0 percent LSD

SEAL TIME	Count	LS Mean	LS Sigma	Homogeneous Groups
3.5	404	0.127951	0.0186341	X
2.5	374	0.412839	0.0193064	X

Contrast	Difference	+/- Limits
2.5 - 3.5	*0.284888	0.0526155

* denotes a statistically significant difference.

Multiple Range Tests for Combined by Starch

Method: 95.0 percent LSD

Starch	Count	LS Mean	LS Sigma	Homogeneous Groups
2	399	0.252857	0.0187684	X
1	379	0.287933	0.0191941	X

Contrast	Difference	+/- Limits
1 - 2	0.0350764	0.0526665

* denotes a statistically significant difference.

The StatAdvisor

This table applies a multiple comparison procedure to determine which means are significantly different from which others. The bottom half of the output shows the estimated difference between each pair of means. There are no statistically significant differences between any pair of means at the 95.0% confidence level. At the top of the page, one homogenous group is identified by a column of X's. Within each column, the levels containing X's form a group of means within which there are no statistically significant differences. The method currently being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0.

Multifactor ANOVA - Combined

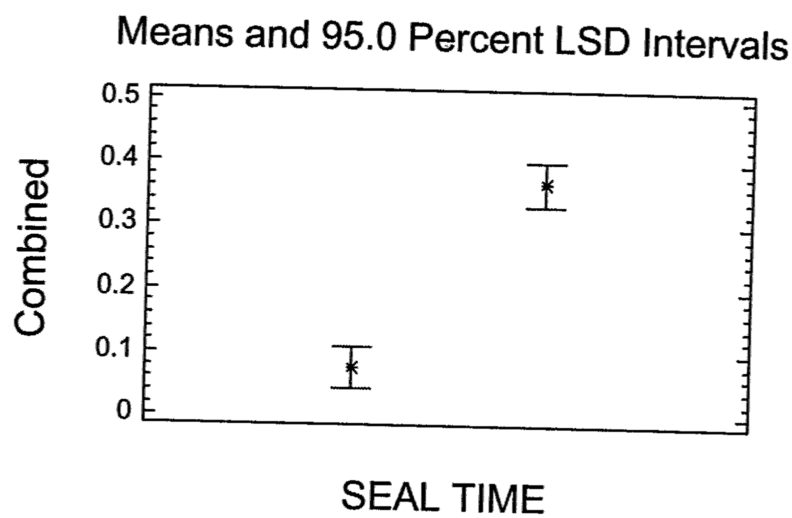
Analysis Summary

Dependent variable: Combined
Factors:
FILL WEIGHT
Temp. F
SEAL TIME

Number of complete cases: 778

The StatAdvisor

This procedure performs a multifactor analysis of variance for Combined. It constructs various tests and graphs to determine which factors have a statistically significant effect on Combined. It also tests for significant interactions amongst the factors, given sufficient data. The F-tests in the ANOVA table will allow you to identify the significant factors. For each significant factor, the Multiple Range Tests will tell you which means are significantly different from which others. The Means Plot and Interaction Plot will help you interpret the significant effects. The Residual Plots will help you judge whether the assumptions underlying the analysis of variance are violated by the data.



Analysis of Variance for Combined - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:FILL WEIGHT	1.84345	1	1.84345	15.74	0.0001
B:Temp. F	29.9043	1	29.9043	255.36	0.0000
C:SEAL TIME	15.1517	1	15.1517	129.38	0.0000
INTERACTIONS					
AB	2.08356	1	2.08356	17.79	0.0000
AC	0.627925	1	0.627925	5.36	0.0206
BC	14.6704	1	14.6704	125.27	0.0000
RESIDUAL	90.2889	771	0.117106		

TOTAL (CORRECTED)	153.775	777

All F-ratios are based on the residual mean square error.

The StatAdvisor

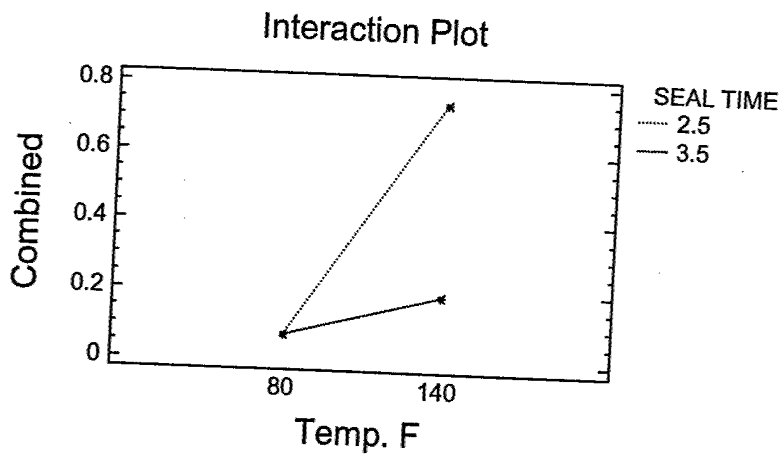
The ANOVA table decomposes the variability of Combined into contributions due to various factors. Since Type III sums of squares (the default) have been chosen, the contribution of each factor is measured having removed the effects of all other factors. The P-values test the statistical significance of each of the factors. Since 6 P-values are less than 0.05, these factors have a statistically significant effect on Combined at the 95.0% confidence level.

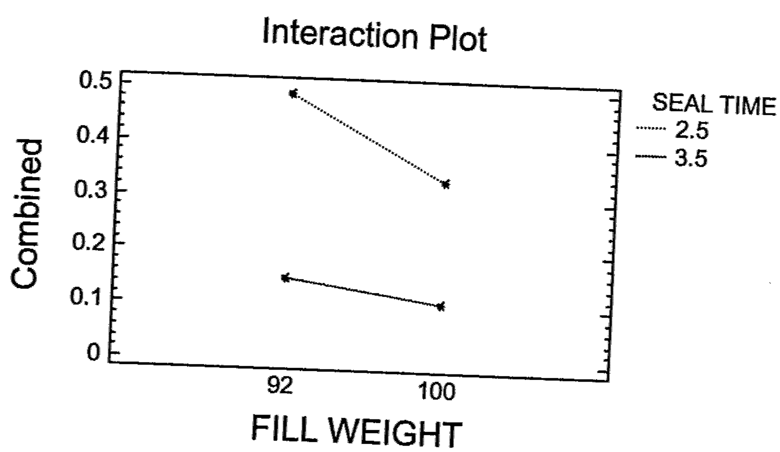
Table of Least Squares Means for Combined
with 95.0 Percent Confidence Intervals

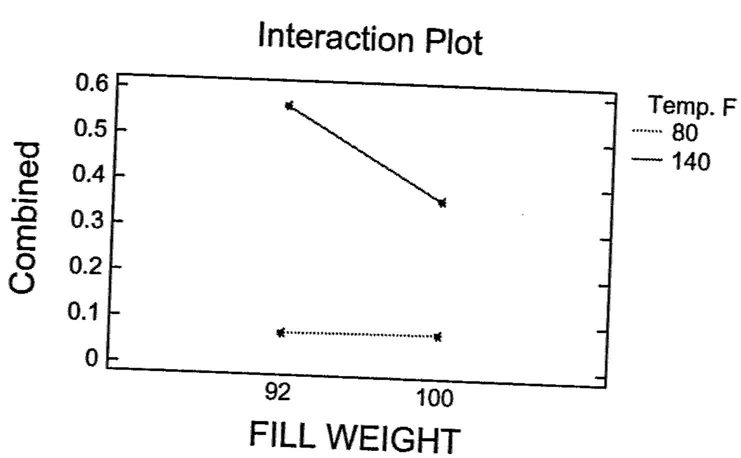
Level		Count	Mean	Stnd. Error	Lower Limit	Upper Limit
GRAND MEAN		778	0.269988			
FILL WEIGHT						
92		403	0.318852	0.0171343	0.285269	0.352434
100		375	0.221124	0.0176882	0.186456	0.255792
Temp. F						
80		379	0.0731675	0.0175881	0.0386955	0.10764
140		399	0.466808	0.0172384	0.433021	0.500595
SEAL TIME						
2.5		374	0.409883	0.0177013	0.375189	0.444577
3.5		404	0.130092	0.0170964	0.0965841	0.163601
FILL WEIGHT by Temp. F						
92	80	185	0.0701048	0.0251599	0.0207922	0.119417
92	140	218	0.567599	0.0232696	0.521991	0.613206
100	80	194	0.0762303	0.0245848	0.0280449	0.124416
100	140	181	0.366018	0.0254364	0.316163	0.415872
FILL WEIGHT by SEAL TIME						
92	2.5	191	0.487263	0.0247676	0.43872	0.535807
92	3.5	212	0.15044	0.0236627	0.104062	0.196818
100	2.5	183	0.332503	0.0252992	0.282917	0.382089
100	3.5	192	0.109745	0.0247218	0.0612908	0.158199
Temp. F by SEAL TIME						
80	2.5	186	0.0752688	0.0250919	0.0260895	0.124448
80	3.5	193	0.0710663	0.0246528	0.0227476	0.119385
140	2.5	188	0.744498	0.0249749	0.695548	0.793448
140	3.5	211	0.189119	0.0237319	0.142605	0.235632

The StatAdvisor

This table shows the mean Combined for each level of the factors. It also shows the standard error of each mean, which is a measure of its sampling variability. The rightmost two columns show 95.0% confidence intervals for each of the means. You can display these means and intervals by selecting Means Plot from the list of Graphical Options.


Interaction Plot
0.8
0.6
0.4
0.2
0
Combined
80
140
Temp. F
SEAL TIME
2.5
3.5


Interaction Plot
0.5
0.4
0.3
0.2
0.1
0
Combined
92
100
FILL WEIGHT
SEAL TIME
2.5
3.5


Interaction Plot
0.6
0.5
0.4
0.3
0.2
0.1
0
Combined
92
100
FILL WEIGHT
Temp. F
80
140

Production Report

STP#1022

1. CORANET Demo Site Process and Packaging Equipment

1.1. The Coranet Demonstration Site

The CORANET Demonstration site is located at the Rutgers University Food Manufacturing Technology Facility at 120 New England Avenue in Piscataway, New Jersey. The facility is equipped with commercial packaging lines (Tiromat Horizontal Form Fill Seal equipment for MRE's and a Raque Heat Sealer for polymeric trays) along with product preparation and filling equipment as well as retort equipment. This equipment is able to demonstrate full scale production of Combat Rations. The CORANET Demonstration Site was used to produce two different Polymeric Tray products (Pork Sausage in Brine and Creamed Ground Beef) under different residual gas levels and retort conditions. After completion of the production run, products were send to the US Army Natick Soldier Center for package integrity and organoleptic analysis.

1.2. Oden Filler

The Oden filler, model: 6-Head Pro/Fill 3000, is a six head pump filler with electronic controls for fill speed, fill volume and nozzle cut off adjustment. The filler can either be gravity fed from a hopper (used for Brine's, Gravy's and low viscosity Sauces) or for the more viscous products via a pressurized manifold system (used for Stew type products). The pressurized manifold system is part of the re-circulation system of the final blend kettle.

1.3. Raque Single Piston Filler

The Raque, model PF2.5-1 is a single piston filler with a hopper (non jacketed, no agitation) and is designed to fill highly viscous sauces and products with particulates. This filler covers a wide range of fill volumes (100 cc to 3400 cc) and has different pistons and nozzles to support this wide range in fill volumes and variety in products.

1.4. Raque Heat Sealer

The Raque Heat Sealer, serial number 93-285-C, is used to evacuate and seal the polymeric tray. The sealer is a continuous motion sealer with four moving seal chambers with a designed maximum capacity of 30 trays/min. Actual maximum capacity might however be limited by vacuum and seal time parameters. The continuous motion, rather than an indexing motion, allows the filling and sealing of the tray with very thin liquids, such as pork sausage links in brine without sloshing of the brine into the seal area. Each sealing head uses a 5" bore, 3 stage air cylinder, which creates (@ 80 psig air pressure) a seal plate force of 3950 lbf (2" rod inside cylinder).

The operation of the Raque Heat Sealer is controlled by various timers. There are three operations occurring in the sealer: "Evacuation", "Sealing" and "Vent". Each operation has two timers, a delay timer and a process timer. The delay timer of each operation starts at the same time, eg at closing of the seal chamber. After the delay timer is timed out, the process timer starts. After the process timer for the sealing operation has timed out, the chamber opens. This means that all operations, including the Vent needs to be completed by the end of the sealing operation. The operation of the Raque heat sealer requires that the vacuum is released during the sealing cycle and therefore does not allow the seal to "set" before the vacuum

is released. This increases the capacity of the sealer but might also cause seal wrinkles due to tension in the lid material when the vacuum is released.

The table below displays the actual maximum throughput capacity (trays/min) of the Raque Heat Sealer as function of seal time and vacuum time.

Vacuum Time Seal Time	0.2 sec	1.0 sec	1.5 sec
2.5 sec	24	19	17
3.0 sec	21	17	15
3.5 sec	18	15	13
4.0 sec	16	13	12
4.5 sec	14	12	11

1.5. Stock Retort

The retort equipment used for this production contract was a Stock model 1100 four cage retort with an Icon-2000 version 2 control system. The retort is a full water immersion cooker with over pressure capability and rotation during all process phases. This retort can process up to 192 polymeric trays per load, using a specially designed rack that supports the tray during rotation. Cycle times are a function of the retort conditions and the product and were determined by a process authority for both a static and a rotational process prior to the production runs.

2. Pork Sausage Links in Brine

2.1. Product Description

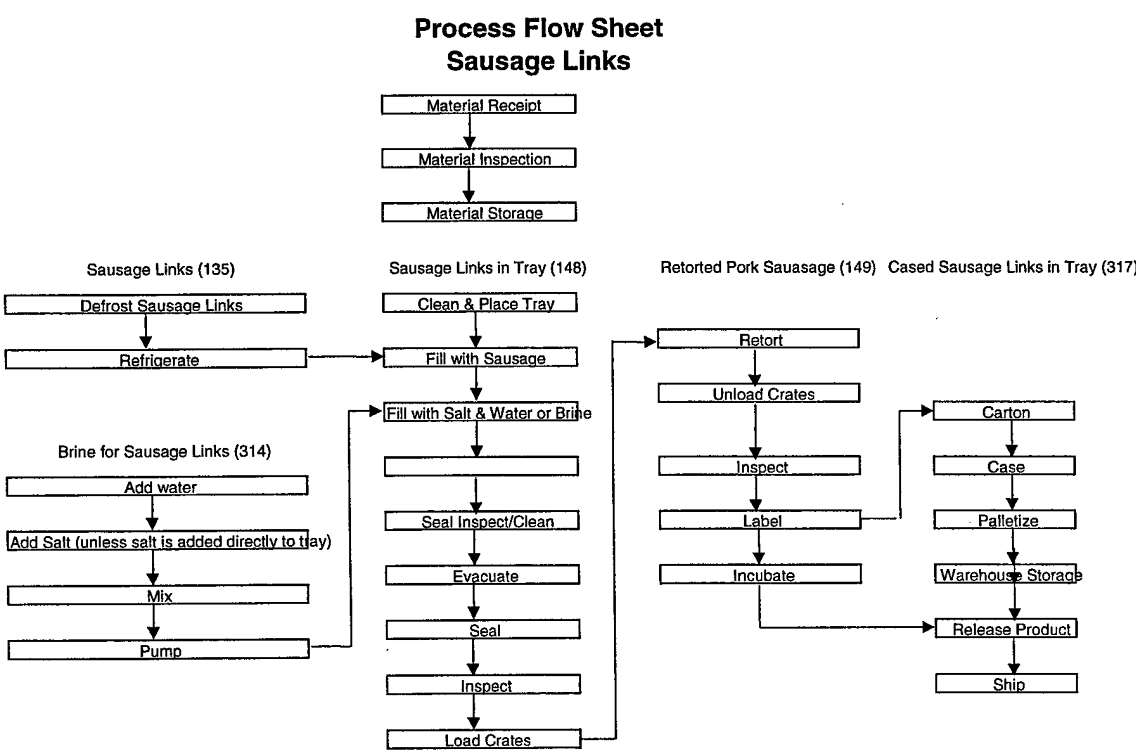
Pork Sausage Links in Brine used in this study complied with the Contract Technical Requirement dated January 11, 2000.

The sausage links were manufactured by ASE Deli/Foodservice Company, St. Charles, IL. and are the same as used by current producers of "Pork Sausage Links in Brine" for Combat Feed Program. The sausage links were precooked by the supplier in order to avoid excessive weight loss during the retort process and each weighs approximately 20 grams before retorting. The sausage dimensions are approximately 3 " long and 1/2 to 3/4" in diameter.

The trays used in these experiments were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

2.2. Process Description



The frozen Pork Sausage Links were defrosted prior to the packaging in the polymeric tray. The trays were then manual filled with sausage links, three rows/layer of approximately 12 sausages/row, two layers. The

trays were weighed and its net weight adjusted to 1440 - 1460 gram by adding or subtracting a sausage link. This method yielded trays with either 72 or 73 links. The trays were then placed on the filling conveyor of the Raque Heat Seal line. The seals were wiped with alcohol to remove any "grease" stains in the seal area that might have occurred during the filling and handling process. Instead of using brine, approximately 25-27 grams of salt was added separately to each tray. The trays were then conveyed to the Raque heat sealer and automatically loaded in the carriers of the sealer. Once in the carrier, water was added to the tray, by the Oden liquid filling system, to ensure that the net weight target was met (90 oz). The Oden system used two pumps and two nozzles to deliver the required volume of water in two stages. The fill speed of the Oden system was adjusted to match the Tray line speed. After the liquid fill, the tray flange area was wiped with a paper towel to remove water spatters that were created by the liquid filling system. The tray was conveyed at a speed of 4 trays/min. while seal conditions were maintained at 412 F for 3.5 seconds. The residual gas inside the tray is determined by vacuum condition at seal time and was controlled by a vacuum timer that opened a vacuum valve for a preset duration.

The Pork Sausage Links were packaged on Raque Heat Seal packaging line under various vacuum conditions. The objective of the production run was to seal product samples a three different residual gas levels:

- 150 cc headspace
- 250 cc headspace
- 350 cc headspace

After the product was sealed in the containers, it was sterilized in either a still full water immersion retort process, or a rotational full water immersion retort process according to a process determined by a process authority.

Each container was visually inspected after the retort process, inserted into a carton sleeve and packed in a lined shipping case.

2.3. Production Data

This product was packaged and sterilized on 8/16/01 and 8/22/01

2.3.1. Packaging Data

- Lot Code: 1228A, 1.0 sec vacuum, 150 cc target, still retort
- Lot Code: 1228B, 0.4 sec vacuum, 250 cc target, still retort
- Lot Code: 1234A, 0.17 sec vacuum, 350 cc target, still retort
- Lot Code: 1234B, 0.17 sec vacuum, 350 cc target, rotational retort
- Lot Code: 1234C, 0.4 sec vacuum, 250 cc target, rotational retort
- Lot Code: 1234D, 1.0 sec vacuum, 150 cc target, rotational retort

Line Speed	4 trays/min					
Seal temp	412 F					
Seal time	3.5 seconds					
Lot Number	1228A	1228B	1234A	1234B	1234C	1234D
Vacuum Time [sec]	1.00	0.40	0.17	0.17	0.40	1.00
Vacuum [inch Hg]	22	16	11	11	17	22

2.3.2. Retort Data

Lot Number	1228A	1228B	1234A	1234B	1234C	1234D
Initial Product Temperature [F]	60	60	64	64	64	64
Retort Come Up Time [Min]	15	15	15	12	12	12
Retort Temperature[F]	252	252	252	252	252	252
Retort Rotation Speed [rpm]	0	0	0	15	15	15
Retort Process Time [Min]	31.0	31.0	31.0	22.0	22.0	22.0

2.3.3. Inspection Data

Lot Number	1228A	1228B	1234A	1234B	1234C	1234D
Trays Retorted	93	91	88	33	33	32
Reject Rate (pre and post retort)	18%	20%	22%	25%	25%	3%
Trays Cased	72	68	64	24	24	24

2.3.4. QC Data

Lot Number	1228A	1228B	1234A	1234B	1234C	1234D
Avg Pre Retort Residual Gas Volume: [cc]	155	257	348	See 1234A	See 1228B	See 1228A
Avg Post Retort Residual Gas Volume: [cc]	123	215	294	309	219	143
Std Post Retort Residual Gas Volume: [cc]	15	19	14	30	5	3
Net Weight [oz]	92.1	91.2	90.8	90.7	90.7	90.3
Drain Weight [oz]	53.2	52.6	52.7	53.9	54.3	-
Fat Content [%]	16.0	16.6	-	-	-	-
Salt Content [%]	2.4	2.4	2.4	2.38	2.37	-

3. Creamed Ground Beef

3.1. Product Description

Creamed Ground Beef used in this study, complies with the Contract Technical Requirement dated January 11, 2000.

The precooked ground beef used for this study was manufactured by St James Gourmet, Farmingdate NY. The ground beef was partial precooked, frozen and packed in bags by the supplier for easier handling. The ground beef was re-blanched at the FMT facility to avoid excessive weight loss during the retort process and thinning of the sauce. Also, the precooking/blanching process removed excessive fat and blood, which otherwise might yield an unacceptable dark product.

The cream sauce was made according to the recommended formula in the product specification with the exception that the starch quantity was reduced from 6% to 5.5%. The three main ingredients: "Starch", "Dry Cream" and "Shortening" were manufactured by respectively National Starch, Bridgewater NJ (Purity W or ThermTex), Quality Ingredients, Burnsville MN (Quali-Cream 7211) and Kerry Inc, Beloit WI (NDX-112 V, Item No. I1529).

The trays used in these experiments were manufactured by Rexam Containers, Union MO and are identified as "Military Steam Table Tray, Type I". The tray weighs approximately 155 grams with a minimal wall thickness of 0.037".

The tray was sealed under vacuum conditions with a Quad laminate film. The film was manufactured by Smurfit Flexible packaging, Shaumburg, IL and is identified as " LC Flex 70466, Green".

3.2. Process Description

The cream sauce was made in a jacketed Groen Kettle, equipped with high speed mixer and scrape surface agitator using the following procedure:

- ❑ Mix required quantity of starch in small quantity of cold water and mix vigorously to form a thin slurry.
- ❑ Add remaining quantity of cold water to kettle.
- ❑ Add Dry Cream to kettle and mix vigorously (speed setting: 2) till all dissolved.
- ❑ Add remaining ingredients (except starch slurry) to kettle and mix while heating kettle till product reaches 180 F to 190 F. Use high heat setting
- ❑ Add starch slurry and the final mixture should be heated to 180 F to 190 F and held at this temperature for 5 minutes. (Use low heat setting once 180 F is reached)
- ❑ Cool down the sauce to 90 F, pump into buckets and refrigerate.

It should be noted that the static retort samples were made with a Purity-W starch from National Starch, while the rotational retort samples were made with a ThermTex starch from National Starch. The TermTex starch does develop its final viscosity during the retort process and can therefore shorten the process time significantly

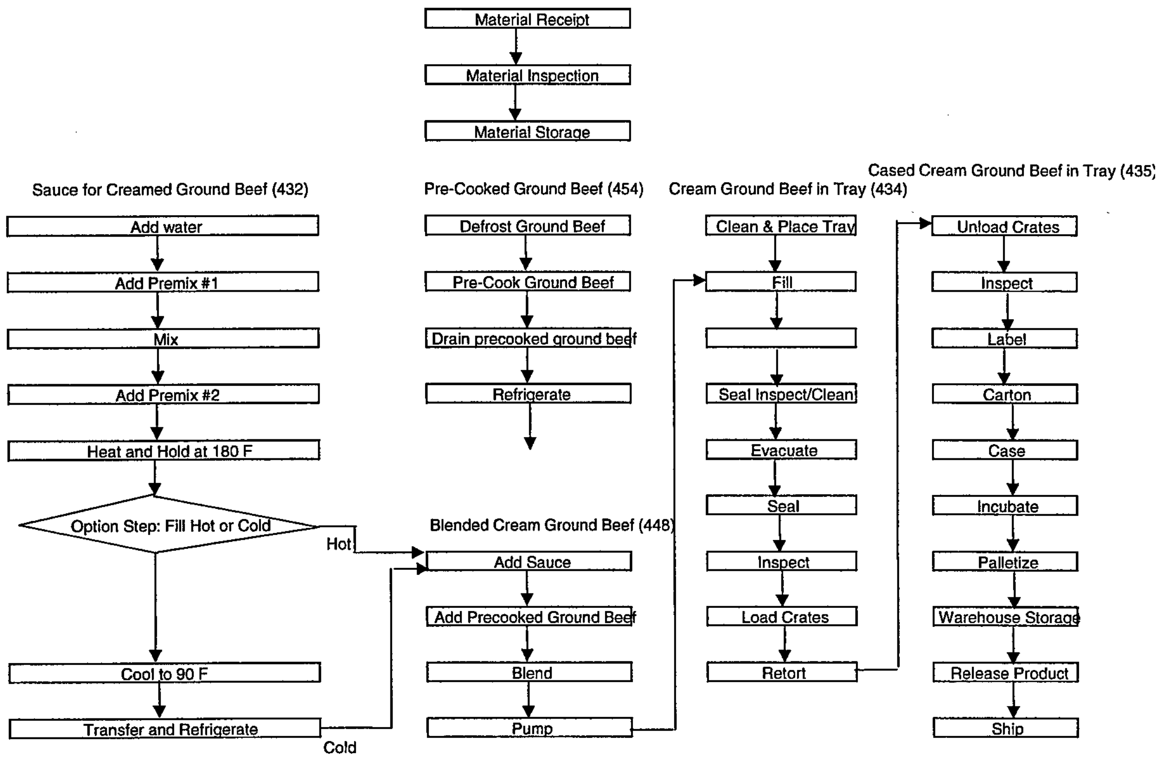
The Beef was cooked in boiling water and then drained. Depending on the use, the beef was either directly used or rinsed/cooled down and refrigerated for later use.

The Creamed Ground Beef was made in the Crazy Kettle by adding first the sauce and then the beef.

- ❑ Add precooked ground beef to the sauce and mix with till uniformly blended
- ❑ Pump blend to the Raque single piston filler hopper as needed.

The trays were placed on the filling conveyor of the Raque Heat Seal Line. The Raque Single Piston Filler filled the tray to a net weight of 92 oz. The trays were then conveyed to the Raque Heat Sealer and automatically loaded in the carriers of the sealer. Once in the carrier, the seals were inspected and when necessary wiped. The trays were conveyed at a speed of 8 trays/min. while seal conditions were maintained at 412 F for 3.5 seconds. The vacuum condition was controlled by a vacuum timer that opened a vacuum valve for a preset duration.

Process Flow Sheet
Creamed Ground Beef



The Creamed Ground Beef were packaged on Raque Heat Seal packaging line under various vacuum conditions. The objective of the production run was to seal product samples with different residual gas levels:

- 150 cc headspace
- 250 cc headspace
- 350 cc headspace

After the product was sealed in the containers, it was sterilized in either a still a full water immersion retort process, or a rotational full water immersion retort process. The process for a still retort was based on a process determined by a process authority on worst case scenario. However, due to the significant impact of residual gas on the heating process in a rotating heating process, on-line heat penetration was performed on seven production trays during each rotational retort process. The cook time was terminated once the F_0 of 7.0 minutes was reached. This resulted into products that had seen a total lethality of at least 11 minutes (additional lethality was accumulated during the cooling process). Had we followed the filed process that was determined by the process authority based on worst case scenario's (30 cc headspace and P-W starch), our process would have been significant longer (~80 minutes).

Each container was visually inspected after the retort process, inserted into a carton sleeve and packed in a lined shipping case

3.3. Production Data

This product was packaged and sterilized on 8/23/01, 8/29/01 and 8/30/01

3.3.1. Packaging Data

- Lot Code: 1235A, 1.0 sec vacuum, 150 cc target, still retort
- Lot Code: 1235B, 0.4 sec vacuum, 250 cc target, still retort
- Lot Code: 1241A, 0.17 sec vacuum, 350 cc target, still retort
- Lot Code: 1242A, 0.17 sec vacuum, 350 cc target, rotational retort
- Lot Code: 1242B, 0.4 sec vacuum, 250 cc target, rotational retort
- Lot Code: 1242C, 1.0 sec vacuum, 150 cc target, rotational retort

<table>
<tr><td>Line Speed</td><td colspan="6">7-8 trays/min</td></tr>
<tr><td>Seal temp</td><td colspan="6">412 F</td></tr>
<tr><td>Seal time</td><td colspan="6">3.5 seconds</td></tr>
<tr><td>Lot Number</td><td>1235A</td><td>1235B</td><td>1241A</td><td>1242A</td><td>1242B</td><td>1242C</td></tr>
<tr><td>Starch Type</td><td>P-W</td><td>P-W</td><td>P-W</td><td>T-T</td><td>T-T</td><td>T-T</td></tr>
<tr><td>Fill Temp [F]</td><td>88</td><td>-</td><td>80</td><td>56</td><td>56</td><td>58</td></tr>
<tr><td>Vacuum Time [sec]</td><td>1.00</td><td>0.40</td><td>0.17</td><td>0.17</td><td>0.40</td><td>1.00</td></tr>
<tr><td>Vacuum [inch Hg]</td><td>20</td><td>15</td><td>11</td><td>11</td><td>16</td><td>22</td></tr>
</table>

P-W: Purity-W starch from National Starch
T-T: ThermTex starch from National Starch

3.3.2. Retort Data

	1235A	1235B	1241A	1242A	1242B	1242C
Initial Product Temperature [F]	84	82	81	58	59	63
Retort Come Up Time [Min]	15	15	15	12	12	12
Retort Temperature [F]	252	252	252	252	252	252
Retort Rotational Speed [rpm]	0	0	0	15	15	15
Retort Process Time [Min]	98.0	98.0	98.0	25.0	26.0	36.0

3.3.3. Inspection Data

	1235A	1235B	1241A	1242A	1242B	1242C
Containers Retorted	90	96	96	40	40	40
Reject Rate (pre and post retort)	20%	5%	6%	5%	5%	0%
Containers Cased	68	88	88	28	28	32

3.3.4. Other QC Data

Headspace analysis retorted product

	1235A	1235B	1241A	1242A	1242B	1242C
Avg Pre Retort Residual Gas Volume: [cc]	166	270	299	-	-	-
Avg Post Retort Residual Gas Volume: [cc]	120	261	310	315	245	123
Std Post Retort Residual Gas Volume: [cc]	8	37	18	35	5	1
Sauce Viscosity [cm/10 sec]	**8.8**	**8.8**	**9.5**	**8.8**	**8.3**	**8.2**
Net Weight [oz]	91.9	**91.4**	92.6	92.7	92.8	92.8
Drain Weight [oz]	**27.9**	**27.2**	30.9	29.9	28.4	**27.2**
Fat Content [%]	7.3	7.2	5.1	6.4	-	-
Salt Content [%]	1.1	1.0	1.0	1.1	-	-

Note: Number is **bold** indicate an out of specification condition.